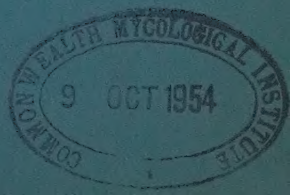


ENDEAVOUR



Volume XIII Number 52

OCTOBER 1954



ENDEAVOUR

The British quarterly scientific journal ENDEAVOUR was first published, by Imperial Chemical Industries Limited, in January 1942. Its purpose is to provide scientists, especially those overseas, with news of the progress of the sciences. While emphasis is laid upon British work, narrow insularity is avoided by publishing numerous articles from overseas contributors and by impartial reference to the world's scientific literature. To make the journal truly international in character it is published in five separate editions—English, French, German, Italian, and Spanish.

No charge is made for ENDEAVOUR. It is distributed to senior scientists, scientific institutions, and libraries throughout the world, the guiding principle being that of helping scientists overseas to maintain those contacts which their British colleagues have always so much valued. Within these limits the Editors are at all times glad to consider the addition of new names to the mailing list.

The drawing on the cover is of the bark Endeavour, which, commanded by Captain James Cook and carrying a number of scientific workers, was sent out by the British Admiralty in 1768 to chart the South Pacific Ocean and observe the transit of Venus

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A quarterly review designed to record the
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of mankind

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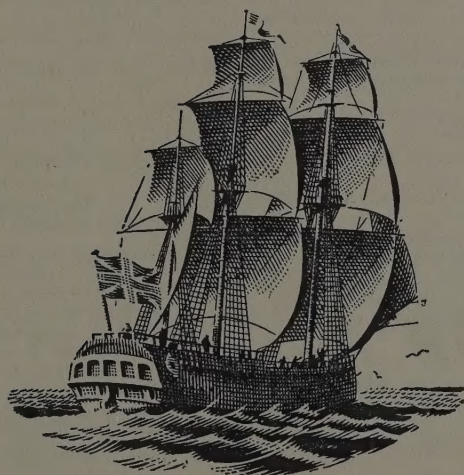
Foreign Editor: J. A. WILCKEN, B.Sc., Ph.D.

Imperial Chemical Industries Limited, Millbank, London, S.W.1

Communications to the Editors should be addressed to North Block, Thames House, Millbank, London, S.W.1

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Sir Charles Parsons (1854-1931)

The remarkable career of Charles Parsons strikingly demonstrates that the development of the individual can be profoundly influenced by both heredity and environment, however fiercely the relative importance of these two factors may be argued. None can doubt that his inventive genius was inherited from his unusually gifted parents or that its practical application—which found its fullest, though by no means only, application in the development of the steam turbine—owed much to the circumstance that his nursery was a well equipped workshop and his childhood toys were engineers' tools. While the steam turbine might have been invented without Parsons—for its principle was not new and the needs of the rapidly growing electrical industry gave inventors of his day a powerful incentive to develop a high-speed steam engine free from reciprocating action—it was surely this exceptional combination of circumstances which resulted in one man making so overwhelming a contribution to one of the greatest of engineering inventions.

Parsons, born on 13th June 1854, was the youngest of the six sons of the third Earl of Rosse, who was an astronomer of high distinction, for six years President of the Royal Society. The six-foot mirror for his great reflecting telescope was cast and polished in his own workshops at the family seat, Birr Castle, Parsonstown, Ireland. For many years this instrument had no rival, and it attracted to the Earl's household many eminent mathematicians and astronomers, some of whom acted as tutor to the family.

When not with his tutors, Charles was constantly with his father in the castle workshops, foundries, and chemical laboratory, and showed great aptitude for doing things with his hands. Even as a boy he was an excellent mechanic, though his ambitious experiments sometimes led him into trouble. Once he ran home with a steel splinter hanging from one eye, the result of the bursting of an air-gun he had made; on another occasion an explosion of gunpowder blew off his eyebrows. He had unusual opportunities for learning seamanship, knowledge of which stood him in good stead later, as the family holidays were spent on their large yacht, the *Titania*.

His father's death in 1867 left him wholly in his mother's care, but happily for his budding genius she was cast in almost as unusual a mould as was his father. She, too, was excellent at every handi-

craft and played her part in the workshops. She was a skilled modeller and became an expert photographer—having a room specially fitted up for the purpose—in the early days of the art.

At seventeen Parsons was sent to read mathematics at Trinity College, Dublin, where his father had been Chancellor, and a year later went to St John's College, Cambridge. In 1877 he passed out as Eleventh Wrangler. It is interesting to note, however, that in his engineering career formal calculation interested him little, and he generally reached his results almost instinctively, by some obscure mental processes which even he himself did not properly understand.

From Cambridge, Parsons went for three or four years as pupil-apprentice at the Armstrong Works, Elswick, and there he translated into practice an epicycloidal engine which had interested him at Cambridge. This engine produced a high rotary speed with little reciprocating action, and may be looked upon as the precursor of his turbine.

In 1881 Parsons went to Kitson's in Leeds, and there continued work on rocket-driven torpedoes which he had begun at Elswick. He was looked upon as socially extraordinary and weird but clearly a great genius. Here an important event took place—he met Katharine Bethell, whom he married early in 1883. His wife shared his anxieties and triumphs, and gave him much support; it is clear, however, that his extreme concentration on his work must often have demanded great understanding on her part.

In 1884 Parsons heard of a good opening with Clarke, Chapman and Company of Gateshead, and he joined them as junior partner. The firm was much interested in electric lighting, which at that time was exciting much attention. To indicate the background to this work it may be recalled that in 1879-80 Edison and Swan were separately working on the incandescent filament, and a year later Sir William Thomson lit his home with Swan's lamps. There was then no public electric supply, but innumerable electric supply companies were being formed to exploit the newly invented dynamo. Parsons appreciated that one of the most urgent engineering needs of the day was for an engine which could drive dynamos directly. Since a high armature speed was desirable, reciprocating action, with its inherent limitations, had to be avoided. In these circumstances the rocket experiments at Gateshead were

put on one side and dynamo and steam turbine experiments were started.

Parsons' first steam turbine patents—his patents eventually numbered more than three hundred in all—were taken out on 23rd April 1884. Unlike earlier inventors who had experimented with turbines, he appreciated that the drop in pressure must be divided into separate steps, each of such a size that the vanes can absorb almost all the available energy of the steam. All large modern turbines incorporate this basic conception. His first compound steam turbine was built in 1884. It developed about ten horse-power and had a speed of about 18 000 revolutions per minute. Later, Parsons introduced important modifications in design, notably the use of a condenser to utilize the low-pressure steam which was at first allowed to go to waste, and of superheated steam at high pressures.

Parsons remained with Clarke, Chapman and Company until 1888, when, anxious to carry out more elaborate and expensive experiments than this firm was prepared to undertake, he set up his own works at Heaton, Newcastle-upon-Tyne. A few trusting friends helped him financially and, after some years of difficulty and anxiety, found their faith and judgment amply justified. Among the difficulties was the fact that the early patents belonged to Clarke, Chapman and Company, so that new developments were restricted. In particular, he was driven to use radial flow of steam, but in 1894 he recovered the patents by agreement and reverted to axial flow, now general practice.

By this time the tide had turned and the inventor began to enjoy the fruits of his labours. The rapidly growing electrical industry, both in Britain and abroad, placed orders for turbines of steadily increasing size. The establishment of his business on a firm footing left Parsons free to develop his ideas in other fields, notably in ship propulsion. In 1894 he fitted up his famous experimental vessel, the *Turbinia*, with which, after initial difficulties, highly satisfactory trials were carried out in 1897. The vessel caused a sensation at the naval review in the Solent which marked Queen Victoria's diamond jubilee in that year. Among the early difficulties may be mentioned that arising from the phenomenon of cavitation, which became marked at the propeller speeds, much higher than any previously experienced, which the direct coupling of turbine and propeller necessitated; this difficulty was largely overcome by modification in propeller design.

The British Admiralty early displayed an in-

terest in Parsons' ship turbines and after installing satisfactory units in smaller vessels used them, in 1906, in the famous *Dreadnought*. Their use thereafter became common practice in the British Navy, and the navies of the world followed this lead. The first merchant ship to be turbine-driven, in 1901, was the Clyde steamer *King Edward*. Cross-channel boats, Atlantic liners, and finally the great Cunarders *Lusitania* and *Mauretania* followed.

The direct coupling of turbine and propeller was inefficient, and adopted only because of the difficulty of transmitting thousands of horse-power through trains of gears, but Parsons realized that reduction gearing—the turbine running fast and the propeller slow—would offer notable advantages; thus slow craft as well as fast could use turbines. He initiated experiments on these lines in 1909 and soon perfected suitable gearing; this entailed cutting the teeth of the gears with exceptional accuracy and using special steels.

Parsons thus lived to see the steam turbine generally adopted both for the generation of electricity from fuel and for the propulsion of the world's naval and merchant fleets. Despite the immense exertions which these achievements entailed, he found time to develop many other interests. Doubtless as a result of his familiarity with the great telescope at his old home, he set up at the Heaton works a unit for manufacturing large parabolic glass reflectors for searchlights; later he took a keen interest in optical glass and in lenses. He acquired a controlling interest in the firm of Ross Limited and also bought up the Derby Crown Glass Works, forming the Parsons Optical Glass Company. He acquired the firm of astronomical instrument makers, Sir Howard Grubb and Company, and transferred the works from St Albans to Heaton, under the name of Sir Howard Grubb, Parsons and Company. This firm has made several very large telescopes, including reflectors of 75-inches aperture for the Radcliffe Observatory, Pretoria, and for the Commonwealth Observatory, Mount Stromlo, Canberra.

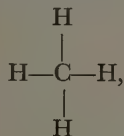
Finally mention must be made of his experiments on the making of diamonds from other forms of carbon. These experiments arose from some he carried out in the 1880s, with the object of making forms of carbon suitable for lamp filaments. He contrived many ingenious methods of subjecting carbon to exceedingly high temperatures and pressures, but although he obtained a few tiny crystals which at first seemed to be diamonds he ultimately reached the conclusion that he could not fully substantiate this claim and so withdrew it.

Some intramolecular electrical effects on the course of chemical change

SIR ROBERT ROBINSON

The electronic theory of organic chemistry, which has so profoundly influenced the development of the subject in the last thirty years, was propounded by Arthur Lapworth and Robert Robinson, who worked independently, but in close consultation, at Manchester University in the third decade of the century. While the author has deprecated the present article as being 'the mixture as before,' it can at least be said that the mixture has proved to possess good tonic properties in the past, and it is probable that it will be as useful in the future.

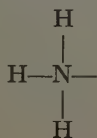
An electronic theory of valency was an almost inevitable consequence of the discoveries of Thomson and of Rutherford, and readers will be familiar with the general idea that the chemist's links between the atoms in a molecule are in fact electrons. Kekulé wrote methane, CH_4 , as



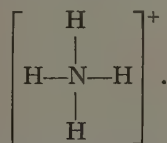
meaning that the quadrivalent carbon atom is bound to a hydrogen atom by each of its four units of chemical affinity. We can use the same symbol as Kekulé, but now each line, representing a valency bond, indicates two electrons shared between the carbon and each of the hydrogen atoms. Obviously H no longer represents a complete hydrogen atom but is really H^+ , a proton, or a hydrogen atom which has lost its one electron.

Although the interpretation in terms of modern wave mechanics is vastly different, we can still usefully employ the old duplet and octet theories of stable electronic configurations, and it is usual to ignore the helium duplet and to say that carbon has four valency electrons. These, together with four from the hydrogen atoms, are all represented in the above formula for methane.

On the same reckoning, nitrogen has five valency electrons, and it is at once obvious why the simplest hydride of nitrogen is ammonia, NH_3 . The nitrogen atom, with five electrons, can take only three more to form the octet, and the symbol is

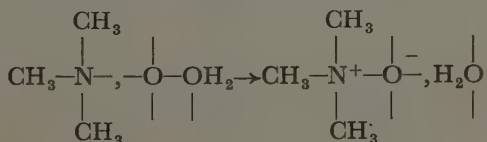


Here the free line represents something that had no place in Kekulé's system. It is what the Americans called 'a lone pair,' two electrons in the valency electron system of nitrogen which are not shared with the nucleus of another atom. However, there is no reason why this unshared pair should not hold a proton, H^+ , giving



Bearing in mind that $\text{H}-$ always means H^+ , it is clear that all the hydrogen atoms are united with nitrogen in the same way. We know that the ammonium ion shown above must have a deficit of one electron, because we regarded it as made from neutral NH_3 and a proton, but this can be confirmed by adding up the number of electrons (8) and the positive charges of the nuclei (9; 5 for N and 4 for 4H). This very simple operation is sometimes illuminating in more complex systems.

The representation of organic chemical reactions involves considerable bandying about of protons. These often change partners, as, for example, when an acid XH ionizes in water to give the hydrated hydrogen ion H_3O^+ . The neutral oxygen atom (with 6 electrons) can similarly be passed from one oxide, or peroxide, to another. Thus the substituted ammonia, trimethylamine, reacts with hydrogen peroxide (which may be looked upon as neutral H_2O plus an oxygen atom) to give an amine-oxide:



Langmuir was the first to point out that the elementary arithmetic mentioned above shows that N in the amine-oxide is positively charged and O is negatively charged. Although the distribution of the electronic atmospheres of the respective atoms should diminish the extent of the separation of the charges, there must be some residual dipole. This is, indeed, proved by direct measurement, and can be collated with a whole series of physical and chemical properties. We can express the nature of such a link by the symbols $(\text{CH}_3)_3\text{N}^+-\text{O}^-$ or $(\text{CH}_3)_3\text{N} \rightarrow \text{O}$.

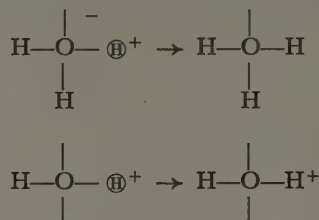
All the so-called co-ordination compounds—formed from certain metallic salts and ammonia, amines, water, and so on—are produced by attack of unshared electrons on the nuclei of the metals. Hence Sidgwick called this type of link the ‘co-ordinate link.’ In all these cases it is apparent that when A— and B combine to form A—B, A is the electron donor and B is the electron acceptor. Adopting plausible analogies, it is possible to extend the allocation of donor and acceptor functions to other molecular species for which there can be no arguing from such elementary first principles.

Lapworth made the appropriate valuable extension of Berthollet's tables of affinity more than thirty years ago. He called the electron donors *anionoid* reagents and the electron acceptors *cationoid* reagents. By these terms he implied substances ‘exhibiting a type of reactivity analogous to that of active anions and cations respectively’. He did not suggest that an anionoid reagent must be negatively charged. Ingold later introduced the terms ‘nucleophilic’ for anionoid and ‘electrophilic’ for cationoid. These are perfectly satisfactory equivalents, but the novelty is confined to the nomenclature, which expresses no fresh idea.

ANIONOID AND CATIONOID REAGENTS

The relationship between anions and anio-

noid complexes is seen from the comparison:



showing that the type of union of O and H is exactly the same in the two cases. Again, we have the active cations, such as those of the diazonium salts, $\text{C}_6\text{H}_5\text{N}_2^+$, and atoms with incomplete electron configurations, such as O and certain metals—for example, Co and Pt in their salts.

It had long been recognized that reducing agents are electron donors—metals such as Na and Zn giving up electrons and becoming cations—and that oxidizing agents are electron acceptors. Thus a ferrous ion, Fe^{++} , gives up electrons to become ferric ion, Fe^{+++} . Ferricyanide, $\text{Fe}(\text{CN})_6^{---}$, accepts electrons to become ferrocyanide, $\text{Fe}(\text{CN})_6^{--}$. It is a short step to deduce the cationoid character of the halogens, ozone, nitric acid, etc.

When we proceed to examine by analogy the electrochemical character of an alkyl group, e.g. CH_3 , we find, as might have been expected from the position of carbon in the periodic system, that it is almost neutral in itself but able to exhibit anionoid or cationoid character according to the electrochemical nature of the atom with which it is combined. In organo-metallic compounds such as zinc methyl, $\text{Zn}(\text{CH}_3)_2$, the metal is ready to give up electrons and the methyl groups are effectively anionoid in consequence.

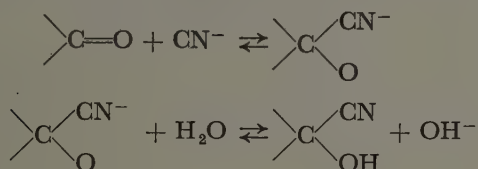
In alkyl halides, such as methyl chloride, CH_3-Cl , the halogen is avid of electrons and the methyl group is effectively cationoid as a result.

These results may be tabulated as follows:

<p style="text-align: center;"><i>Electron Donors (anionoid)</i></p> <p>Active anions, OH^-, CN^-. Anionoid complexes, R_3O^-, NR_3^-. Reducing agents; certain metal ions, such as Fe^{++}; $\text{Fe}(\text{CN})_6^{---}$. Organo-metallic compounds, such as R in RMgHal, RLi, R_2Zn.</p>	<p style="text-align: center;"><i>Electron Acceptors (cationoid)</i></p> <p>Active cations, H^+, $\text{C}_6\text{H}_5\text{N}_2^+$. Atoms with incomplete electron configurations: O, Co, Pt, etc. Oxidizing agents; certain metal ions, such as Fe^{+++}; $\text{Fe}(\text{CN})_6^{--}$; halogens. Radical attached to potential anion, R.Cl, $\text{R}-\text{OSO}_2\text{C}_6\text{H}_5$.</p>
<p>Unsaturated carbon in ethylene, $\text{CH}_2=\text{CH}_2$, and benzene,</p> <div style="text-align: center;"> </div>	<p>Unsaturated carbon in carbonyl compounds such as formaldehyde, $\text{H}_2\text{C}=\text{O}$, and acetone, $(\text{CH}_3)_2\text{C}=\text{O}$.</p>

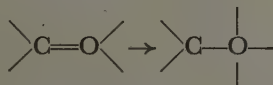
The additions to the table below the line are of great importance. They are made without taking mechanism into account and simply as a recognition of a characteristic type of reactivity. They find a place not merely on consideration of their interactions but on consideration of the electrochemical character of the group or atom which becomes attached to groups such as >C=O in ketones.

Thanks in large measure to the researches of Lapworth, there was from an early date a clear example in the case of the formation of cyanohydrins. The CN^- anion attacks (reversibly) the carbon of >C=O , and the complex ion so formed attacks some proton donor, such as water, producing cyanohydrin and a new anion:



The whole chemical behaviour of carbonyl compounds is consistent with the conception that the carbon of >C=O is cationoid. Another example is the reaction with organo-metallic compounds, whereby the anionoid alkyl group becomes joined to carbon of carbonyl. Naturally, this does not mean that the carbonyl group as a whole is inert towards acids as sources of protons. The result of such interaction would be a protonide, e.g. >C=OH^+ , and in this entity the electron-attracting propensities of the carbon atom will be greatly enhanced by the net positive charge of the molecule.

Inspection will show that the electrons of the carbonyl group undergo a displacement in the course of the addition of cyanidion:



An electron pair has broken away from C and remains attached to O. This is a completed displacement and could be represented as

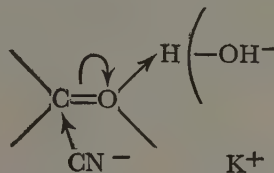


The writer wished, however, to express also a fractional displacement of the same type and for

this purpose introduced the symbol \curvearrowright . In

the present case, $\text{>C=O} \curvearrowright$ means a breaking

away from C (but remaining with O) of electrons covalently binding C and O, the extent being undetermined and up to a maximum of two electrons. Furthermore, there is no evidence that the steps in cyanohydrin formation are sharply defined, as suggested above, and the whole process may be represented by the expression



Union of O with H probably begins before the cyanidion has established a full covalency with C.

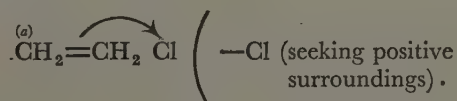
Turning now to unsaturated carbon in such groups as C=C , we find that the characteristic, facile reactions are with cationoid agents—for example halogens, oxidizing agents in general, or acids. On the other hand, this kind of unsaturated carbon does not combine easily with organo-metallic compounds, amines, or cyanidion. It is true that under special conditions some of these reactions can be forced, but they are not characteristic. Hence ethylene and its analogues are anionoid and their reactions are at least initiated by exhibition of an electron-donor property

symbolized by $\text{CH}_2=\text{CH}_2 \xrightarrow{(a)} \text{CH}_2=\text{CH}_2 \xrightarrow{(b)}$. This represents

a polarization of undetermined magnitude, and it is the unshared electrons, or fractional electrons acquired by (b), which seek centres of electron-defect in other molecules. The electron defect on (a) will be made up by the approach of anionoid centres at some stage, and probably before the new covalency with (b) is fully established.

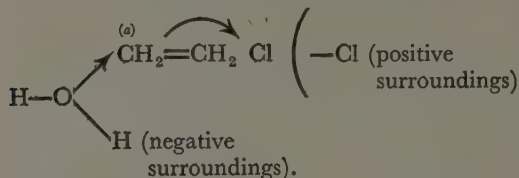
As another example of the use of our symbolism for almost synchronous processes the formation of ethylene chlorohydrin from ethylene, chlorine, and water may be mentioned.

1st stage



2nd stage

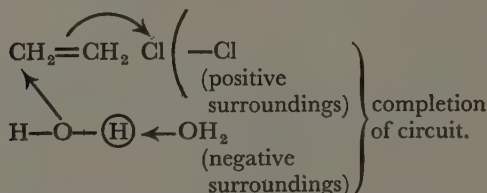
When the defect on (a) is large enough it is neutralized by an anionoid water molecule.



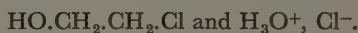
3rd stage

For the reason discussed above in relation to amine-oxide, the water molecule becomes positively charged, and a proton is lost to form H_3O^+ with another H_2O molecule.

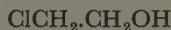
The complete circuit is therefore



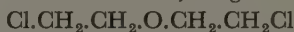
The electron pair can move round the circuit to the limited extent required, until we get



This process has also been interpreted as the addition of HOCl to $\text{CH}_2=\text{CH}_2$, but kinetic experiments have not favoured this view and have shown, *inter alia*, that the chlorine molecule is enormously more reactive than hypochlorous acid. In addition, the process can be carried out in alcohol (ROH) instead of in water, and the result is then $\text{RO} \cdot \text{CH}_2 \cdot \text{CH}_2 \cdot \text{Cl}$. In fact, as



accumulates in the solution, we get



as a by-product. A cyclic scheme like this has the great advantage that it avoids the large energy changes which independent ionization would require. In the cycle we gain on the swings what we lose on the roundabouts.

M. J. S. Dewar, followed by a number of modern investigators, has predicated a stage before the first of those given above. The π -electrons, which are those active in double bonds, are supposed to form a π -complex such as

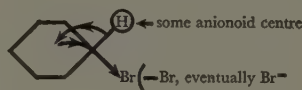


This conception has a certain resemblance to the old ideas of residual valency, which were, for example, brought into service to explain the nature of hydrocarbon picrates. It is of philosophical interest in connection with absolute mechanism, and has some practical bearing on certain stereochemical aspects of reaction processes. It does not, however, help much in orientation problems, that is, in predicting the direction taken by the chemical change being examined.

The π -complexes, if formed at all, must be very labile, and when they break down they form one or other of the systems which we have represented with the aid of the curved and straight arrows. It is a stage that in the majority of cases we can very well omit for practical purposes.

The facile reactions of benzene and its closer analogues are with the more powerful cationoid reagents, and in no case with anionoid reagents. The products are, however, obtained by substitution rather than by addition, because of the power of resisting disturbance which the very stable electronic configuration of benzene confers on the molecule.

As an example we may take the bromination: $\text{C}_6\text{H}_6 + \text{Br}_2 \rightarrow \text{C}_6\text{H}_5\text{Br} + \text{HBr}$. The overall processes can in this case be represented as follows:



In this simplified expression the curved arrows represent merely unsaturated electrons taken from the nucleus to form a link with a bromine atom and other electrons returned to it in compensation.


CONJUGATIVE ELECTROMERIC
DISPLACEMENT

A large part of organic chemistry is concerned with systems made up of various combinations of the anionoid and cationoid groups (and their obvious analogues; for example SR_2 with OR_2 and NR_3 ; $\cdot\text{CN}$, $\cdot\text{NO}_2$, $\cdot\text{NO}$ with $\cdot\text{CO} \cdot$). Thus, if we join together two anionoid complexes of the R_2O , R_3N type we get the hydrazine and peroxide systems, $\text{R}_2\text{N} \cdot \text{NR}_2$, etc. Two strongly cationoid groups of the carbonyl type afford the α -diketone, $\text{R} \cdot \text{CO} \cdot \text{CO} \cdot \text{R}$, system (related, by extension, to the quinones).

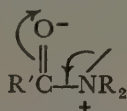
Neutralized system

A very instructive case is the union of a strongly anionoid and a strongly cationoid group. This the

writer has called a 'neutralized' system, because the typical reactivity of each centre is diminished by intramolecular electromeric displacement. Thus, in the amides we have $R'(C=O).NR_2-$ (unshared electrons), and the separate reactivities

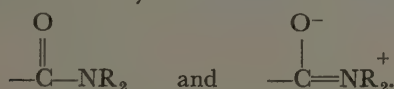
are indicated in the symbol  $R'C(=O)NR_2 \rightarrow$.

The way is open for internal satisfaction of the opposing tendencies, and the actual position is

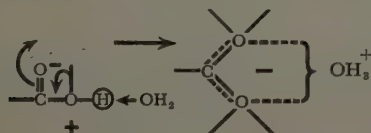



which implies a number of properties.

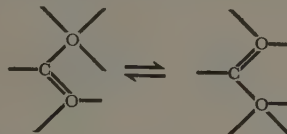
1. That the resting molecule is a dipole; this is confirmed by actual measurement of the dipole moment. The dipole is the cause of the molecular association of the amides, which in turn is evinced by a relatively high boiling-point. Nylons are substances whose long-chain molecules contain amide groups, and the disposition of the dipole groups in contiguous chains is one of the important factors affecting the physical properties of the assemblages of macromolecules. The writer may perhaps be permitted to say that this view of amides (and of carboxylic acids and esters) was expressed by him in partial valency form in 1920, and was used in lectures and teaching from 1922 in the electronic form; it was repeated specifically in 1926. At first the exponents of the resonance theory overlooked this and put forward the conception that the amides were hybrids between the extremes:



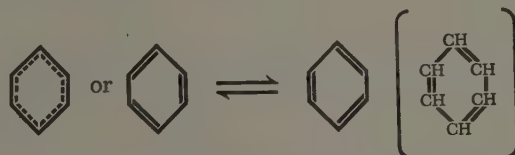
That is precisely the meaning of the expression with curved arrows quoted above, and after some years this method of representing resonance (or mesomerism) has been widely adopted. Carboxylic acids and esters are quite similar in kind, though not in degree, in their electromeric displacement; the 'acidity' of the carboxyl group is evidently due primarily to the repulsion (or weaker attraction) exerted on the proton by the positively charged oxygen atom.



In the carboxyl ion it is impossible to distinguish between the oxygen atoms, so that this looks like a case where  means the displacement of one electron. Nevertheless, the wave mechanicians may not approve of this and may prefer a dynamic, or extremely labile, system:



The problem is similar to that presented by the benzene ring:

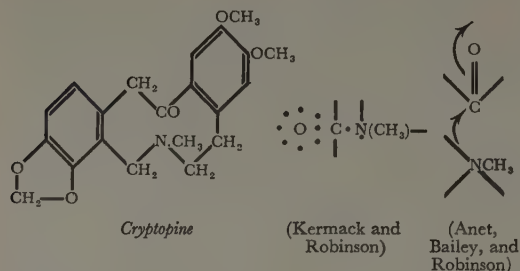


2. That the cationoid character of the carbonyl must be diminished; this occurs in varying degree. It is never entirely suppressed, as is shown by the reaction of suitable amides with organo-metallic compounds or with reducing agents such as metallic sodium or lithium aluminium hydride. In esters the carbonyl group is more active than in amides, because OR_2 is a weaker electron donor than NR_3 . Condensation reactions of the Claisen type are manifestations of the cationoid carbonyls, and so are the ester exchange reactions under the influence of RO^- anions. Nevertheless, the carbonyls of amides, carboxylic acids, and esters are definitely less reactive than those of aldehydes ($R.CO.H$) or ketones ($R.CO.R'$).

3. That the anionoid character of the amine moiety of amides should be reduced. It is apparent that if we use the unshared electrons within the molecule to a certain extent, they will to the same extent be unavailable for donation to protons or other cationoid centres externally. Hence the amides are far weaker as bases than the amines from which they are derived. This is one of the facts about amides which is learned in the most elementary study of the subject. Again, the basic strength is only greatly diminished; it is not entirely suppressed.

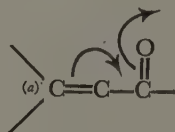
Amide-type neutralization of $>C=O$ and NR_3

across intramolecular space was suggested by the writer in 1922 (with W. O. Kermack) in the case of cryptopine, and was experimentally confirmed in 1953 (with F. A. L. Anet and A. S. Bailey) in this and other examples.



Catio-enoid systems

Ethylene is a weaker anionoid group than ammonia, and direct union of an ethenoid (unsaturated) carbon group with a carbonyl group produces a correspondingly weaker neutralization of the carbonyl reactivity. The system is not so tightly knit as in the amides, and each moiety can function independently. Nevertheless, the conjugative electromeric displacement represented by the symbol



is a potentiality very frequently realized in practice.

This displacement has the very interesting effect of transferring the electron defect of the carbonyl carbon to the terminal carbon of the ethenoid system. The latter thus becomes cationoid at (a). Thus the quality of reactivity of the carbonyl group has been transferred to the ethenoid centre (a), and this group can now be attacked by cyanidion and other active anions and anionoid reagents.

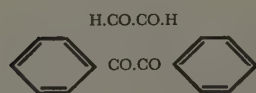
Still more extended systems are possible, for example



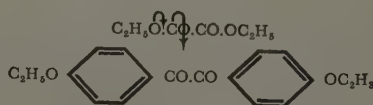
and we can combine the catio-enoid system with an anionoid complex,



The expected properties have been noted in the laboratory, and an example which the writer has used is given by the following comparisons:

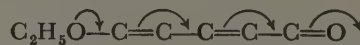


Yellow, and reactive in a cationoid sense.



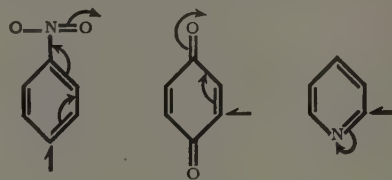
Colourless, and much less reactive in a cationoid sense.

In the group $\text{C}_2\text{H}_5\text{O.CO.}$ we have a directly neutralized system, as above. In



the neutralization operates through two double bonds.

Catio-enoid systems are at work in many reactions of aromatic systems with anionoid reagents, and some of the better known types are: (1) the hydroxylation and amination of nitrobenzene; (2) the Thiele acetylation of quinones; and (3) the Tschischibabin amination of pyridine.



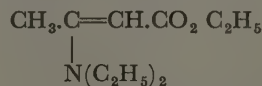
The sign \leftarrow indicates the point of entry of the anionoid reagent. It will be seen that the three types are distinguished by the position of the cationoid group, which can be (1) wholly outside the nucleus, (2) partly in the nucleus, and (3) wholly in the nucleus.

Apart from these and similar types, the reactions of aromatic compounds are always with cationoid reagents.

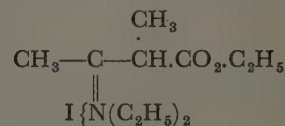
Hetero-enoid systems

The writer's interest in these topics arose to a large extent in the study of the reactions of substances of this class from 1915 onward. The processes were interpreted in terms of partial valency symbols, which were translated into electronic terms from about 1921.

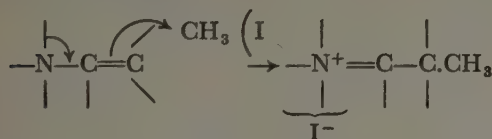
In these systems an anionoid complex (or anion, such as O^-) is directly attached to an ethenoid group and powerfully reinforces its anionoid reactivity. Thus,



on combination with CH_3I yields

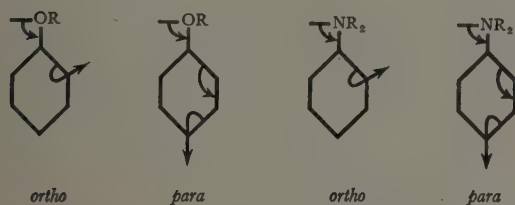


the process being



The most important examples of such systems are the aromatic amines and the phenols.

The reactivity of benzene towards cationoid reagents (diazonium salts, bromine, nitric acid, sulphuric acid) is enormously increased by the amino or hydroxyl substituent, and the position taken up by the entering group is determined as *ortho* or *para*:

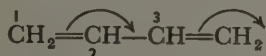


Apparently paradoxically, the activity of unshared electrons is greater the smaller their number, $N > O > F$, the reason being the approach to the rare-gas configuration as the number increases. Nevertheless, even the halogens can take part in hetero-enoid systems to an extent sufficient to control the orientation of entering substituents derived from cationoid reagents:

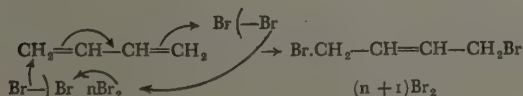


Polyenoid systems

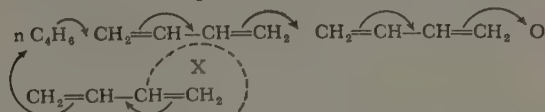
Here one ethenoid group reinforces another, as in the simplest case, that of butadiene,



Anionoid reactivity is enhanced, but by no means so markedly as in the hetero-enoid systems. The electron defect on C^3 is transferred to C^1 exactly as in the case of the catio-enoid systems. A completed additive process involves the movement of the double bond:



A characteristic reagent which induces polymerization of butadiene is a peroxide, and the process can be represented as:



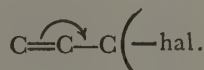
The end group at X must then react in some different manner. The reactions of benzene



are frequently represented as being similar to those of butadiene and it may well be asked—why does not benzene polymerize? The answer may be that the electromeric displacements in benzenoid substances have a very much smaller amplitude than those in butadiene, on account of the restoring force of aromatic stability.

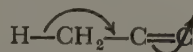
Other conjugated electromeric systems

The allyloid system



is well established, and also those involved in keto-enol tautomerism (including reducibility of α -halogeno-ketones), Hofmann and other elimination reactions, carbinolamine formation, and in a great variety of molecular rearrangements.

A doubtful position is occupied by what is called hyper-conjugation,



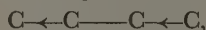
The writer thinks this is really hypo-conjugation, a second-order effect, if it exists at all. Certainly a great deal of the evidence advanced in favour of the phenomenon can be interpreted in a different manner, and the suggestion should be regarded as *sub judice*.

All these conjugated electromeric processes obey the rule of conservation of the electronic configuration of the atoms, and this rule discloses the position and electrochemical character of points of reactivity. In general, the effects are repeated at $\alpha\gamma$ positions.

It is now necessary to look at another kind of intramolecular electrical effect, one which was in fact the first to be recognized.

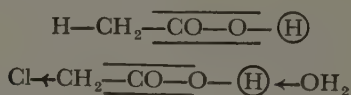
DIRECT (INDUCTIVE) ELECTRICAL EFFECT

J. J. Thomson pointed out that atoms, like those of chlorine, with a relatively large and concentrated nuclear charge (as compared, for example, with hydrogen or carbon) strongly attract covalency electrons binding them to atoms of lower atomic numbers. This follows from simple electrostatic principles, the electron atmosphere being diffuse. The result must be a drift of electrons represented by the symbol $\text{Cl} \leftarrow \text{C}$ and a dipole moment, $\text{Cl} \leftarrow + \text{C}$. Whether we consider a direct inductive effect through space or one set up in a series of contiguous condensers,



there is obviously here an important electrical effect which can be studied experimentally by a physical method and which should be capable of being collated with reactivity in regard to both rate and orientation. The simplest applications are to the strengths of acids and bases. Groups like $\text{O}_2\text{-N}^+ - \text{C}$ and $\text{Cl} \leftarrow \text{C}$ substituted for $\text{H} - \text{C}$, anywhere in the molecule, invariably increase the strength of an acid.

The positive field moves the electron sheath of the oxygens, and one interpretation of this is that the repulsion exerted by the oxygen nucleus on the attached proton is thereby increased. It is therefore relatively easier for a solvent molecule (such as H_2O) to detach it.



The above is naturally a purely pictorial expression, in which the parallel horizontal lines represent the electron atmosphere in the vicinity of the carboxyl groups of acetic and chloroacetic acids.

Predictions are fulfilled in examples involving groups and atoms of unequivocal chemical character. The effect, like all inductive effects, diminishes rapidly with increasing separation of the source of the disturbance and the carboxyl group. At a certain distance it becomes quite small and hardly observable. The following data for dissociation constants are typical:

$\text{CH}_3\text{.CH}_2\text{.CH}_2\text{.CO}_2\text{H}$	$K = 1.6 \times 10^{-5}$;
$\text{Cl.CH}_2\text{.CH}_2\text{.CH}_2\text{.CO}_2\text{H}$	$K = 3.0 \times 10^{-5}$;
$\text{CH}_3\text{.CHCl.CH}_2\text{.CO}_2\text{H}$	$K = 8.94 \times 10^{-5}$;
$\text{CH}_3\text{.CH}_2\text{.CHCl.CO}_2\text{H}$	$K = 1.39 \times 10^{-3}$.

The difference between a factor of 3.0 and one of 1.6 is only just significant in this field. The step from 3.0 to 8.94, however, is beyond the limits of

experimental error. The large change when the chlorine atom moves from the β - to the α -position is unmistakable, and is characteristic of the inductive effect.

A study of the effect on the strength of acids and bases resulting from substitution of hydrogen by alkyl groups indicated the possibility that the group $\text{CH}_3 - \text{C}$, as compared with $\text{H} - \text{C}$, distributes a negative electrical field, $\text{CH}_3 \rightarrow \text{C}$, but the values observed were always too small to have clear significance.

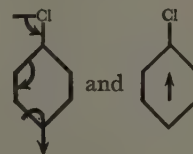
$\text{H.CH}_2\text{.CO}_2\text{H}$	$K = 2.1 \times 10^{-5}$
$\text{CH}_3\text{.CH}_2\text{.CO}_2\text{H}$	$K = 1.4 \times 10^{-5}$
$(\text{CH}_3)_2\text{CH.CO}_2\text{H}$	$K = 1.5 \times 10^{-6}$
$(\text{CH}_3)_3\text{C.CO}_2\text{H}$	$K = 9.8 \times 10^{-6}$

A better answer was given by studies of dipole moment in the aromatic series. The moment of *p*-nitrotoluene was found to be approximately the sum of that of toluene and of nitrobenzene.

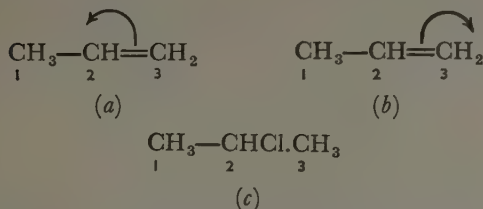
The direction of the displacement caused by the nitro group is known, and hence that caused by the methyl group must be in the same direction in the molecule of *p*-nitrotoluene. That means that it is of opposite electrical character, as illustrated in the accompanying diagram, in which the arrows indicate the direction of electron drift:



L. E. Sutton made a great contribution by demonstrating experimentally, by measurement of dipole moments, that an electromeric effect in which electrons move into the benzene nucleus can co-exist with an inductive effect such that electrons drift in the opposite direction. Thus

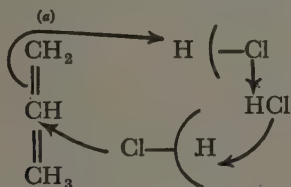


can occur together in the molecules. Roughly speaking, the inductive effect controls rate of reaction of the molecule as a whole and the electromeric effect controls orientation, with the very important qualification that where there exists more than one potential electromeric process, the electrical fields over the whole molecule may decide which of the possible systems is operative, and in which sense. This is an indirect control of orientation, and an example is provided by additions to simple unsymmetrical ethylenes:



Propylene could undergo electromeric polarization as in (a) or as in (b). But the electron push (relative to H) of the CH_3 group (see above) evidently favours (b). Hence the anionoid centre is C^3 , and at this point the cationoid H of HCl is taken into the molecule, leaving C^2 to combine with Cl^- .

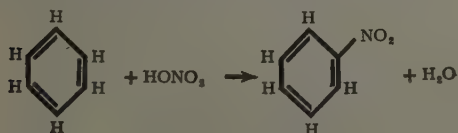
Once again, the purely ionic interpretation is too crude. Many writers nowadays would say that a carbonium ion, $\text{CH}_3\text{C}^+\text{H}\text{CH}_3$, is formed, and that this then combines with chloridion. The writer considers that all such processes go through gradations in a cycle, and that Cl^- begins to go in before the union with H^+ is completed,



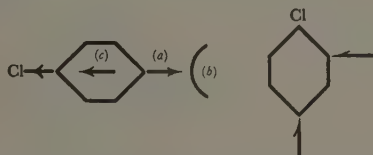
but the cycle is initiated by (a).

SUBSTITUTION IN THE BENZENE NUCLEUS

The example above is one in which Markownikov's rule (that the halogen atom combines with the carbon already joined to the greater number of carbon atoms) applies, and the agreement with prediction is excellent over the whole field. In this open-chain series there are nevertheless certain complications, such as the two modes of addition of hydrobromic acid (one in the presence and the other in the absence of peroxides), the arguable importance of steric factors, and, on the practical side, the difficulties encountered in separation and analysis of the products of reaction. Almost all these doubts and difficulties are less, or even non-existent, in the study of substitutions in the benzene series; by this we now imply substitutions by means of cationoid reagents. The most widely used of the latter is nitric acid, which affords nitro-compounds, often in very high yield:



In recent years, studies of the kinetics of nitration in the presence of sulphuric acid have been interpreted (Bennett, Ingold) with the aid of the theory that nitronium, NO_2^+ , is the active agent. It is hard to credit that this is universally true. For example, in facile nitrations in aqueous or acetic acid solution, formation of a cationoid complex, $\text{NO}_2^+-\text{OH}^-$, seems more probable. The point is immaterial for the present discussion, however, as the reagent is certainly cationoid. Hence sites of nitration (\leftarrow) are simply points in the ring where unshared electrons may be found and where the subsequent processes can be completed. If these electrons are represented below by (a) and the cationoid reagent approaches from (b) then a positive field, indicated by (c), will tend to inhibit the formation of the new covalency by binding (a) closer to the carbon atom of the nucleus:

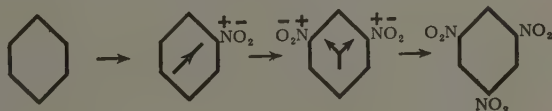


Because of the electrical field set up by the $\text{Cl}-\text{C}$ dipole, the nitration of chlorobenzene, $\text{C}_6\text{H}_5\text{Cl}$, is much slower than that of benzene. Toluene represents the opposite case:



The field in this instance facilitates substitution: toluene nitrates faster than benzene. These, it must be realized, are not electromeric effects in themselves, and, as was discussed in the case of strength of acids, the operation is from almost any part of the molecule on any part of the molecule.

The nitro group is itself dipolar, so that the difficulty of nitration increases in the series benzene, nitrobenzene, dinitrobenzene:

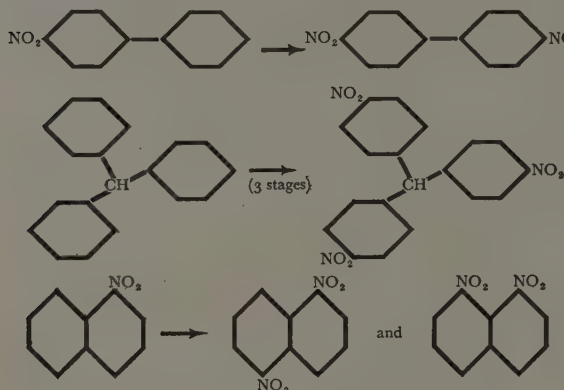


In fact, the last stage, to trinitrobenzene, is so difficult to effect as to make it impracticable on an industrial scale.

Working some years ago in Oxford, G. Müller found that nitration to trinitrobenzene could be effected with a cold mixture of nitric and perchloric acids, but this is a method which is hardly

likely to recommend itself to a manufacturer. The trinitro-compounds have valuable properties as explosives, and the one made on a large scale is trinitrotoluene (TNT), because the increase of reactivity produced by the methyl group is sufficient to enable us to reach the trinitro stage in a convenient process.

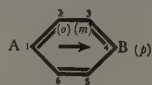
Since the inductive effect dies away as the source of it becomes more distant, we naturally find that substances whose molecules contain more than one benzene ring nitrate first in one nucleus and then in another:



The extreme stability of pyridinium salts towards cationoid agents is due to the fact that the nucleus is positively charged. Hence any unshared electrons produced in electromeric processes are very tightly held and are, in fact, almost inert:

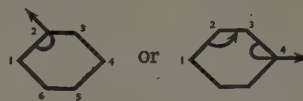


If we now consider a benzene nucleus under the influence of a field such that electrons



tend to move in it in the direction of the arrow (the *ortho*, *meta*, and *para* positions being expressed relative to A) it is evident that this can be produced by an electron push from A or by a pull from B. The former will, as we have seen, result in increased reactivity, and the latter connotes a decrease of reactivity. The push must operate most strongly from C¹, and the pull will be strongest at C⁴ and weakest at C¹. The electron potential will therefore fall in the series C¹, C², C³, and C⁴. The most facile electromeric process

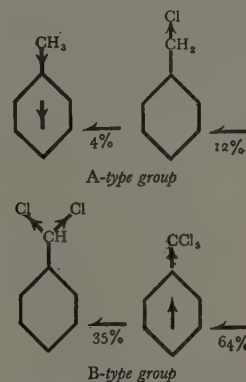
must accordingly be something originating from C¹, either



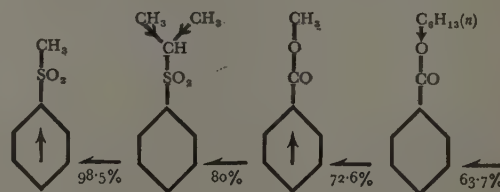
Thus an (A) group causes nitration in the *ortho* and *para* positions with greater ease than in benzene.

For exactly the same reason a substance containing a (B) group is nitrated in the *meta* position (*ortho* to A in the diagram) or, as often happens, the (B) group is itself displaced (*para* to A in the diagram).

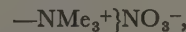
If we start with a group of (A) character we can—by introduction of halogen atoms, nitro groups, or ammonium centres—effectively convert it into a (B) group:



The figures indicate the percentage yield of *meta* derivative according to the nature of the original substituent. Transformation of a B-type group to an A-type is less easy:



A quaternary ammonium salt grouping,



produces completely *meta* nitration when it is directly attached to the nucleus; substantially more than 90 per cent *meta* nitration when separated from the nucleus by one carbon atom; but when two carbon atoms distant from the nucleus, the *meta* nitration drops to 10 per cent. A nitroxyl ($-\text{NO}_2^+$) is about equivalent to ($-\text{NH}_3^+$) in this series, but it must be remembered that amines

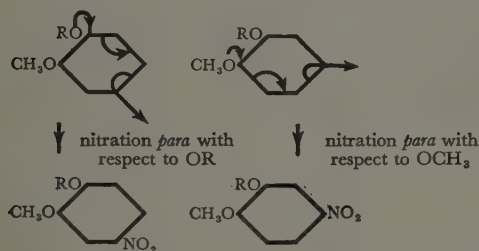
bearing a hydrogen atom on the nitrogen do not exist entirely as salts, even in strong acid solution. The non-onium moiety, though minimal in concentration, nitrates rapidly.

As already stated, the conjugated electromeric systems are dominant in orientation, and yet the orientating power of hetero-atoms (O, N, etc.) directly attached to the nucleus can be modified by field effects.

It occurred to us at Manchester to test the hypothesis of the combined electrical effects by studies in the catechol and quinol series, and an interesting contrast between the two was noted. The outcome was readily explicable on the molecular field hypothesis, and may indeed be regarded as a proof of its essential correctness.

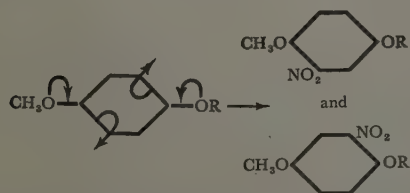
The alkyl ethers of both catechol and quinol are practically quantitatively mono-nitrated in acetic acid solution by not much more than the theoretical amount of nitric acid. In the catechol ethers the substitution is exclusively *para* to oxygen, and in the quinol ethers there is nothing except *orthonitration*.

The substitutions are both due to activation of two electromeric systems of the hetero-enoid type, and when two different alkyl groups are used on the two oxygens the orientating power of the two systems must be different. In our experiments one of the groups was always methoxyl:



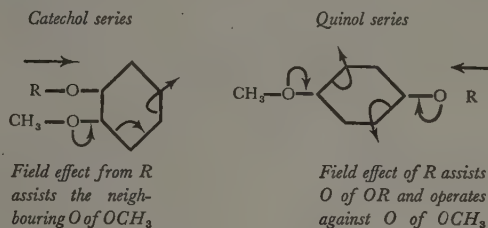
These products could be independently synthesized, and, by means of a melting-point curve for mixtures of the two isomerides, any mixture produced in the nitration could be accurately analysed.

The case of the quinol ethers is exactly parallel:

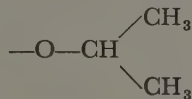


It was in fact found that the orientating power of

OR, even when R was a higher alkyl group, could be varied considerably. For example, we found the directive power (taking CH₃O as 100) of the group CH₃→CH₂→O— to be 135 in the catechol series and 164 in the quinol series. The explanation is that any push from R producing a field effect must help both oxygens in the catechol series (thus diminishing the disparity) but will help one oxygen and hinder the other in the quinol series:



Thus, as the field effect of R was increased the orientating power of OR in the quinol series rose continuously, until with C₁₈H₃₃O it was as much as 212. But in the catechol series the orientating power reached a maximum (150) at



and then fell. The reason was clearly that the field was more and more distributed over both oxygen atoms as the alkyl chain was increased in length.

In this brief review no attempt has been made to cover the subject, but merely to give the elementary theoretical background for a limited number of plain examples of the operation of a molecular electrical field on a reactive centre.

In conclusion, the writer would like to point out that the charges on the nuclei of the atoms are as important as those on the electrons, and this is especially true in comparisons of stereoisomerides and the like. When two conformations are possible, the more stable should be that in which the nuclei of the atoms achieve the greater separation. Thus, a *trans* form of a disubstituted ethylene should be more stable than an isomeric *cis* form, and this is well known to be so. The greater stability of the chair form of cyclohexane as compared with the boat form is another example of the tendency to gain stability by a maximum separation of the nuclei. It is simply a special case of a more general rule, and it may be well to remind ourselves that in the last resort the whole molecule, and not just a part of it, must be considered in estimating the degree of *trans* quality.

On keeping wild animals in zoos

A. URBAIN and J. C. G. NOUVEL

The keeping and breeding of animals in captivity is both of direct zoological importance and of general educational interest, and in recent years has been the subject of considerable research. Much has been learnt of the needs of many species in regard to accommodation, diet, and the prevention and treatment of disease. Of particular interest is the demonstration of the fallacy of the belief that animals in the wild are free to roam at will; in point of fact very many factors restrict their movements and the natural state is not one of freedom.

From the earliest times, man has exhibited in public places all manner of wild animals—elephants, bears, lions, tigers, hyaenas. The ancient Egyptians were past-masters in the exhibition of wild animals and used the same methods as we do today for capturing their specimens—nets, traps, living bait, and, for birds, nooses and bird-lime. Furthermore, the lay-out of their cages was on a system closely resembling that of the oldest of present-day zoos.

A modern zoo differs considerably, however, from the older establishments in the conditions of life provided for the animals. They are to be seen in natural settings, at liberty among stones or in grassy meadows. Water-fowl have lakes; birds of prey are housed among rocks on which they can easily find a perch.

Besides this, the animals must be able to run, to climb, to jump, or to fly, according to their habits, which involves giving them ample space. This is essential for the maintenance of good health; it is also a necessary condition for satisfactory breeding, though this depends even more on the provision of an adequate diet. Feeding and comfort are the two basic problems of raising wild animals in captivity.

HABITAT

The criticism most often made of the practice of keeping animals in captivity is directed against the limited space at the animals' disposal. This limitation is emphasized by the fact that animals in the wild seem able to roam at will, and that nothing prevents them from fleeing before the advance of man. Moreover, the bars which separate the animals from the spectators have unhappy associations with prisons.

These ideas are, however, largely fantasies. Observation shows that animals in the wild state are by no means able to roam about at will. The development of the concepts of region of dispersal,

biotope, and territory is based on recognition that an animal is limited in its movements not only by biogeographical conditions, but by the presence in its neighbourhood of predatory species or of animals of the same species that are maintaining their own territories. Migration is often thought of as a journey freely undertaken, but as we come to understand the underlying mechanism we find that the long and hazardous trip is in fact forced upon the animal by external or internal changes, such as the approach of cold weather or phases of sexual development. The state of nature is by no means a state of complete freedom.

An alleged proof that captive animals are cruelly restricted in the space available to them is the fact that they do not avoid man, as do almost all animals in the wild. However, flight is produced by the appearance of man only if he is regarded as an enemy. In the Antarctic, where man is rarely seen, and in the various national parks and game reserves, animals show no fear of man. Moreover, captive animals do not seek to avoid a spectator who draws close to their enclosure, though if this same visitor enters the enclosure itself, the animals will at once seek to escape. Only certain keepers, and these the most skilled at their profession, are able to attract some of the animals to themselves; in this the complete confidence they inspire in the animals is probably an aid. All this indicates that the avoidance of man by animals is not automatic, but occurs only when the animals regard man as inimical; the question of space limitation is quite irrelevant.

The earliest enclosures for wild animals consisted of pits or palisades. Cages were soon introduced, and are still to be seen in our older zoos; nowadays, however, there is a tendency for their bars to be replaced by less obvious barriers such as bodies of water or broad ditches. This improvement in technique has undoubtedly done more to remove the prison-like atmosphere of the older



FIGURE 1 - The graceful black swan, *Chenopsis atrata* (Latham), native of Australia, which has been nesting since January. This photograph and those that follow were taken at the Parc Zoologique du Bois de Vincennes and illustrate the great variety of wild animals for which suitable accommodation and diet must be provided.



FIGURE 2 - White pelican, *Pelecanus onocrotalus* L., interesting because of its curious shape and the use to which it puts its beak.



FIGURE 3 - The Eld deer, *Cervus (Panolia) eldi* M. Clelland, from the North of India and Indo-China, is now very rare. In Paris it maintains the seasonal rhythm that it follows in its native country.



FIGURE 4 - Giraffes, *Giraffa camelopardalis* L. These are of a fairly common species, which has been reared in many zoological gardens.



FIGURE 5 - Polar bear, *Thalarctos maritimus* Phippe, an arctic species still only rarely reared in captivity, although it is represented in most zoological gardens.



FIGURE 6 - Red river hog, *Potamochoerus porcus* L., African swine frequenting marshes and the banks of rivers.



FIGURE 7 – Black-necked, or West African, crested crane, *Balearica Pavonina* L. This African crane is characterized by the crest on the nape of its neck and by its cry, which is composed of two different notes.



FIGURE 8 – *Ciconia ciconia* L., migratory species of stork which winters in Africa and nests in Europe. Here its nest is at ground level.

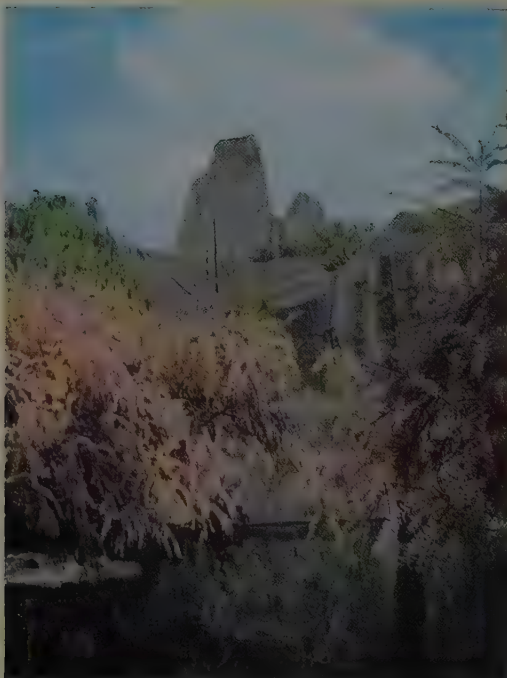


FIGURE 9 – Spring landscape in the Vincennes Zoo. The teal pool is surrounded by tamarisks (*Tamarix tetrandra*); in the background is the silhouette of the 'Grand Rocher.'

FIGURE 10 – The kitchen of the Vincennes Zoo. Here are prepared all foods which have to be cooked, as well as some special diets.



zoos than acceptance of the arguments given above. Progress can, however, be only slow, since much work has to be done for each species in turn in order to provide inconspicuous but perfectly safe barriers.

DIET

The problems of diet [1, 2] are as important as those of habitat. The first guide in fixing the diet of a captive animal is a study of its digestive system. Yet, even if systematists teach us to distinguish carnivores, herbivores, insectivores, and so on, observations on animals in the wild show that these terms are by no means absolute and that animals which consume only a single type of food are extremely rare. We are thus led to modify diets at present in use when relevant observational data of the wild state are acquired.

Another method of determining an animal's diet is to present it with several alternative foods and to note the ones it prefers. This method is most useful with recently captured animals, which are presented with foods obtainable from their natural habitat; it may be misleading when applied to animals accustomed to captivity. The latter may consume an excess of some palatable food to the exclusion of a necessary component of the diet, or may refuse a food regularly eaten in wild nature because they have become unaccustomed to it. An example of the first type is provided by several species which, when the zoo is crowded with spectators, will consume large quantities of bread, refuse their normal rations, and sometimes die as a result of indigestion. The second case is illustrated by captive animals which refuse one of the foods normally taken by their wild companions if it is presented to them. This refusal is usually only temporary, and a taste for the unfamiliar food is more or less quickly acquired.

The monkeys and apes, particularly the anthropoids (gorillas, chimpanzees, and orang-utans) [3], are particularly difficult to feed. What, for example, is the natural food of the gorilla [4]? This ape spends the hours of daylight in search of its food, which is varied. In the Cameroons it shows a great liking for a little red berry which is commonly found in small bunches. This berry contains a violet pulp, with an acid taste, enclosing a number of blackish pips which may be found in gorillas' faeces. The natives call this fruit the 'esson'; it belongs to a plant of the group Scitaminae. The gorilla also likes the buds of sugar-cane and the pith of the banana tree (which it prefers to the fruit). Termites are a special

delicacy, and it will also steal the eggs from birds' nests.

In captivity, the gorilla, like the other anthropoids, has different requirements. It needs a substantial and varied diet in a fresh and wholesome condition. The table below gives the daily rations of the female gorilla 'Solange,' which has been in captivity since 1931:

Cooked meat	250 g
Vegetables:	
Carrots	300 g
Cabbage or lettuce	2000 g
Cooked potatoes	150 g
Fruit, according to season:	
Peanuts	100 g
Bananas	250 g
Dates, figs, oranges, or apples	300 g
Bread	250 g
Milk	0.5 l
Eggs	2

The following table gives the daily ration of the chimpanzees at the Psychological Laboratory of Yale University, at New Haven, Connecticut; this laboratory is under the direction of Dr Yerkes. A chimpanzee weighing about 22 kg receives daily a ration of 1694 g, providing 2670 calories. This ration is made up of a special biscuit ('chim-cracker'), supplemented by fruits and vegetables.

<i>Composition of biscuit</i>						<i>g</i>
Wheat flour .. .. .	..	..	..	..	..	1200
Toasted wheat .. .. .	..	..	..	..	..	2200
Maize flour .. .. .	..	..	..	..	..	2200
Crushed oats .. .. .	..	..	..	..	..	1000
Powdered bones .. .. .	..	..	..	..	..	350
Powdered milk .. .. .	..	..	..	..	..	400
Salt .. .. .	..	..	..	..	..	50
Peanut butter .. .. .	..	..	..	..	..	1200
Raisins .. .. .	..	..	..	..	..	920
Molasses .. .. .	..	..	..	..	..	455
<i>Composition of supplement</i>						<i>g</i>
Cabbage .. .. .	..	..	..	..	..	150
Carrots .. .. .	..	..	..	..	..	175
Onions .. .. .	..	..	..	..	..	125
Bananas .. .. .	..	..	..	..	..	300
Oranges .. .. .	..	..	..	..	..	230
Potatoes .. .. .	..	..	..	..	..	200
Milk .. .. .	..	..	..	..	..	50
Peanuts .. .. .	..	..	..	..	..	114

The daily ration consists of 350 g of biscuit and 1344 g of fruit and vegetables. The chimpanzees on this ration keep in excellent health and breed well.

Variety in the diet is not in itself enough to ensure the maintenance of life. Some species have particular requirements. An example is the white-coated Colobus monkey (*Colobus abyssinicus occidentalis* Rochbrune). This monkey will survive in captivity only if it receives an abundance of leaves of the vine (*Vitis vinifera* L.), mulberry (*Morus alba* L.), or aucuba (*Aucuba japonica* Thunb.). These cannot be effectively replaced by salads, cabbage, cress, spinach, or any kind of fruit. What is it that these leaves contain that makes them essential to the animals' survival? It is unlikely to be a known vitamin, since the other vegetables contain vitamins, and vitamin supplements fed to the animals have been found to be ineffective. We think it is more probable that the leaves contain minute quantities of certain other factors, whose effect on the tissues has been demonstrated by Gabriel Bertrand.

The food of carnivores is not usually restricted to lean meat. The great felines, which traditionally receive such a diet in captivity, in the wild state eat certain vegetables, and also the viscera of their victims, particularly the liver. The latter is known to be rich in biologically essential substances, as is illustrated by the large number of medical preparations into which it enters more or less directly. On the other hand, the canines and hyaenas possess a powerful digestive system and can live a healthy life, and even reproduce in captivity, on a diet composed exclusively of meat. In the wild state, nevertheless, these animals, too, have a most varied diet, as is shown by the list of foods consumed by the fox in the wild state [5]. The rearing of certain foxes for their fur has revealed some requirements of these animals that had not become apparent under the less exacting conditions of the zoo. The mustelidae and the civets, although allied to the carnivores, are much less easy to satisfy in their feeding requirements.

Contrary to the impression which these examples may have given, it is not always safe to assume that related families of animals have similar nutritional needs. With mammals in general one can assume the same diet to be appropriate to a whole zoological family, but there exist specimens whose requirements are very different from animals nearly related to them. The fennec fox (*Fennecus zerda* Zimm.), for example, is as nice in its choice of food as the other foxes are catholic in theirs, and the ferret (*Mustela putorius furo* L.), which can live and reproduce in captivity on a diet consisting exclusively of bread and milk, differs in this respect from most of the other mustelidae.

The problem of feeding herbivores is quite different. In the wild, these animals may partake of 50 to 100 different vegetable species [6-9]. In captivity, no attempt is made to reproduce such a diet, and the feeding is usually based more or less on the known needs of similar domestic species. The multiplicity of plant types comprised in ordinary forage crops is usually enough to provide a satisfactory regimen for the captive herbivores, and even to enable them to reproduce. In some cases, however, a special diet is necessary. The best known example is the roe-deer (*Capreolus capreolus* L.), which, although common in the French forests, is difficult to keep in captivity in spite of the daily provision of the leaves of blackberry (*Rubus idaeus* L.) and ivy (*Hedera helix* L.) which in nature make up the greater part of the diet during the cold weather. Other examples are the giraffes (*Giraffa camelopardalis* L.), which reproduce consistently at the zoo at Vincennes. In addition to their ration of forage and grains, they receive oat flakes, carrots, bananas, onions, cress, and branches of the locust-tree (*Robinia pseudacacia* L.) during the seasons when this is possible.

Following the work of Raybaud [10], and of Urbain and Guillot [11], we feed to all our herbivores a substantial quantity of germinated grain. The grains are soaked in water for 24 hours and then kept in special containers for 2 to 3 days, until the radicle emerges. The animals prefer these to dry grains. The experiments quoted above have shown that animals on this diet put on more weight and keep in a better condition, but the biological reasons for this result have not yet been discovered.

Other observations have shown that, in the present state of knowledge, the best method of ensuring a satisfactory existence for captive animals is to supplement a balanced basic ration with small quantities of very varied foods.

PATHOLOGY

Satisfactory nutrition has the additional effect of reducing the incidence of disease, but the pathology of animals in captivity is none the less of great importance. Certain virus diseases are particularly feared in zoos, which from time to time introduce animals collected in all parts of the world. Rinderpest, detected simultaneously in London and Paris in 1865 by Bouley [12] and Leblanc [13], is as contagious as foot-and-mouth disease, whose rapid spread is all too well known. These two diseases attack mainly animals with cloven hooves (e.g. bovines, pigs). They constitute a serious menace to

domestic animals, and in consequence all countries impose severe measures to prevent their spread. Bouley has shown that, in zoos, strict isolation and rigid precautions can limit their spread without the need for a policy of wholesale slaughter. Swine fever is just as contagious, but happily it attacks only commoner and less important species. A form of typhus found among zoo carnivores, which has not yet been transmitted to domestic species, is a serious menace, but it can be prevented from appearing by a vaccination procedure due to Urbain [14].

Among birds, roup is fairly uncommon, and Newcastle disease has not yet been encountered in zoos. The most important disease is psittacosis, which again is the subject of strict health precautions, the more so because it is transmitted easily from birds to man, in whom it often proves fatal.

Microbial infections also cause trouble in zoos. Anthrax and glanders are spread among carnivores by the accidental feeding of infected meat. The organisms responsible for swine erysipelas and pseudotuberculosis do not usually cause severe outbreaks of disease, but they appear from time to time in a number of species of mammals and birds, as do other *Pasteurellae* and *Salmonellae*. Tetanus and botulism are rare, but various types of gangrene frequently occur; these can be overcome nowadays by the use of the appropriate antibiotics. Tuberculosis is a serious zoo disease [15]; it is fairly common in mammals and birds, causing 10–20 per cent of all adult deaths. However, it seems to be on the decline at present, and Ratcliffe [16] has shown that correct feeding can lessen its incidence.

Parasitic diseases are important, though somewhat less widespread. The commonest fungal parasites are species of *Aspergillus*, which mainly attack penguins and young geese. Keds (sheep-ticks) cause little trouble even when present in large numbers, but mites on birds, and those which

cause mange in mammals, were a serious problem until the modern synthetic insecticides were introduced. Unfortunately, these substances are toxic to reptiles and to the smaller mammals and birds.

Finally, the zoo pathologist is faced with wounds and accidental injuries which each year produce a number of fatalities. Medical aid is often of little help in these cases, but a careful study of their causes in relation to the animals' behaviour can often prevent their recurrence.

ANIMAL PSYCHOLOGY

Psychological analysis of animal behaviour is one of the most fruitful studies that can be carried out in a zoo. The behaviour of the animals in relation to the available space and to the physical factors of their surroundings plays a large part in the organisation of the zoo. The reaction of certain animals to others of different species governs the relative positions of the different enclosures, and intra-specific relations govern the make-up of groups or herds in which mortal combats can often be prevented only by building up a social hierarchy such as is found in the wild state. Finally, the behaviour of the animals towards man will influence the practice of those in charge.

Apart from their direct importance in the running of zoos, however, these observations have a greater interest when they concern advanced species, whose cerebral and psychic development approach that of man. The line of approach pursued by Koehler and Yerkes, and followed subsequently by others, allows us to hope that one day—beginning from tropisms, the most elementary reactions of living matter, and proceeding by way of conditioned reflexes and behaviour—we shall be able to analyse the mechanism of instinct and perhaps of intelligence itself. The latter, too long considered a perquisite of man alone, must now be attributed to many different species.

REFERENCES

- [1] URBAIN, A. *Bull. Ass. franç. Sci.*, **62**, 191, 1933.
- [2] *Idem*. *Bull. Soc. Sci. Hyg. aliment.*, **32**, 137, 1944.
- [3] URBAIN, A. and RODE, P. 'Les Singes anthropoïdes.' Presses Universitaires de France, Paris, 1946.
- [4] URBAIN, A. *Sciences*, **35**, 53, 1940.
- [5] SCHOENICHEN, W. 'Taschenbuch der in Deutschland geschützten Tiere'. Berlin, 1938.
- [6] JACOBI, A. 'Das Rentier, eine zoologische Monographie der Gattung Rangifer'. Leipzig, 1931.
- [7] LEOPOLD, A. 'Game Management.' New York and London, 1939.
- [8] HUBBACK, T. J. *Mammal.*, **20**, 1939.
- [9] GROTE, H. *Z. Jagdkde.*, **5**, 7, 1943.
- [10] RAYBAUD, L. *C.R. Soc. Biol.*, **92**, 437, 1925; **94**, 665, 1926.
- [11] URBAIN, A. and GUILLOT, G. *Rev. Zootech.*, No. 12, 339, 1931.
- [12] BOULEY. *Rec. Méd. vét.*, **2**, 849, 1865.
- [13] LEBLANC, U. *Ibid.*, **2**, 945, 1865.
Idem. *Bull. Soc. cent. Méd. vét.*, **1**, 6, 1866.
- [14] URBAIN, A. *C.R. Soc. Biol., Paris*, **120**, 836, 1935.
- [15] URBAIN, A. *Ann. Inst. Pasteur*, **61**, 705, 1938.
- [16] RATCLIFFE, H. L. *Amer. Rev. Tuberc.*, **54**, 389, 1946.

The evolution of particle counters

H. GREINACHER

The ready availability of a wide range of radioactive isotopes, and of specific compounds containing them, has led to their extensive and fruitful application in many branches of science, medicine, and technology. Counting devices, necessary for assaying the rate of emission of particles, have in consequence become of general scientific importance. The evolution of counters and the principal characteristics of some present types are here reviewed.

Counting methods date from the discovery by E. Elster and H. Geitel in 1903, simultaneously with W. Crookes, that when α -particles strike zinc blende (ZnS) flashes of light are produced. This provided a very simple means for detecting and counting α -particles, which Rutherford used in the well known experiments that led to the formulation of the Rutherford-Bohr model of the atom. This scintillation method had, however, the disadvantage that the observations were very laborious, and that no permanent record was possible.

THE PROPORTIONAL (GAS MULTIPLICATION) COUNTER

A considerable step forward was made in 1908, when E. Rutherford and H. Geiger [1] found a method for detecting and counting α -particles by means of their ionizing action. This ionization effect was too small for direct measurement with the means then available, but they attained their objective by multiplying the number of ions formed by one particle by means of collision ionization. This was done with the device shown diagrammatically in figure 1. A wire of 0.5 mm diameter passes axially through a metal cylinder Z, and is connected at one side to a quadrant electrometer Q, and at the other to a radioactive resistor R. The tube, across which a P.D. of about 1000 volts is applied, is exhausted through the connection P until the pressure is reduced to a few centimetres

of mercury. If an α -particle travels through the thin mica window at F, a current pulse passes. The electrometer shows a deflection, which rapidly vanishes because the electrical charge leaks away through the resistance.

The process in the tube is as follows. The α -particle ejects electrons from the gas molecules. These accelerate towards the wire as they enter an increasingly intense part of the electrical field. By collision with gas molecules they produce new electrons, which in turn produce more by collision, and so on. In this way an avalanche of electrons is produced, and the original ion charge is multiplied very greatly, becoming large enough to measure. The degree of multiplication increases with the applied voltage, but the voltage must not be too high or continuous discharge sets in. The duration of the discharge process is about 10^{-4} sec; the electrons themselves discharge in 10^{-6} sec, but, because of their lower velocity entailed by their much greater mass, the positive ions simultaneously present take longer to reach the wall of the tube. In spite of the rapidity of the discharge process, the inertia of the needle of the quadrant electrometer originally employed prevented more than 3-5 particles per minute being recorded. The proportional counter, in its original form, was at first little used; it found general application only with the introduction of 'counter tubes' twenty years later. Nowadays the method is among the fastest, and by it a million particles a second can be counted. An advantage is that the current pulse is proportional to the primary ionization. Thus α -particles can be counted independently of any β -particles, since these have about 100 times weaker ionizing power.

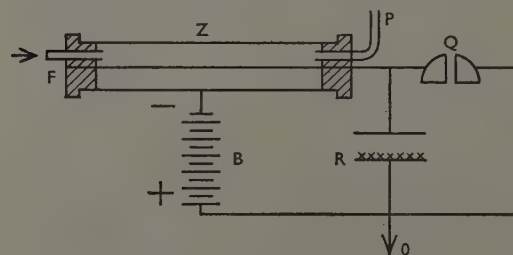


FIGURE 1 - Proportional counter.

THE POINT COUNTER

At first interest turned in the direction of the point counter (figure 2) described by Geiger [2] in 1913, though this is now largely displaced by

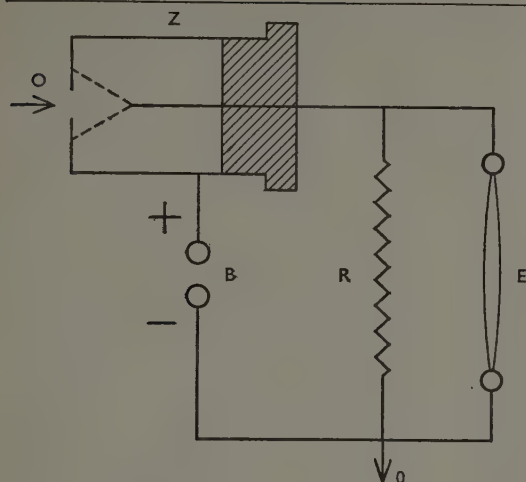


FIGURE 2 - Point counter.

the Geiger-Müller counter. A pointed wire projects into a small metal cylinder *Z*, and is connected with a rapidly responding string-electrometer *E* and a resistor *R* of 10^8 to 10^9 ohms. A voltage of 1000–2000 volts is applied to the cylinder; this is somewhat below the discharge potential. If a particle now passes through the window *O*, which is either open or covered with thin aluminium foil, discharge occurs momentarily from the point and the electrometer registers a pulse. The reason for the immediate interruption of a point discharge is to be found in the space-charge effect. It can easily be understood if it is imagined that a negative potential is applied to the cylinder. Then we have, as with a proportional counter, a slowly drifting positive ionic cloud following the rapid discharge of the electron avalanche. Until this cloud is discharged at the casing, it opposes the applied field, which thus cannot produce another discharge. Unlike the early proportional counter, this instrument responds to, and counts, α -, β -, and γ -particles. For demonstration purposes it suffices to fill it with air and to use an outgassed point, but for instrumental purposes the point is replaced by a small sphere (0.1–3 mm diameter), and many different gases are used. The sensitive volume, i.e. the space in which the particles are counted, is shown with dotted lines in figure 2. If the potential applied to the cylinder is increased, the pulse amplitude increases, but the pulse rate stays nearly constant. There is thus a so-called 'plateau,' the slope of which is given by the relative increase of pulse rate per 100 volts rise of applied voltage.

The time which must elapse between the passage of two successive particles if they are to be separately recorded depends on the course of the process in the interior of the counter, and on that in the external circuit. Complete counting evidently occurs only if the charge transferred has completely leaked away through *R*.

If the capacitance of the wire plus electrometer is *C*, the decay of the electrometer voltage is given by $V = V_0 e^{-t/CR}$. The potential thus falls to $1/e$ of its value in a time $\tau = CR$. The time constant τ thus determines the rapidity at which the charge leaks away, and therefore the resolution-time of the instrument; thus, if *C* = 10 picofarads and *R* = 10^9 ohms, it is $1/100$ th of a second. This does not necessarily mean that all the α -particles from a sample which on the average gives off 100 particles every second, will be counted. The emission of particles is not at all a regular event, so that some of them always escape counting because they come off too soon after the previous one. However, the proportion which thus escapes can be determined mathematically if the resolving power is known. Because of the statistical distribution of incoming particles, the mean particle-count per second can be determined with accuracy only if a sufficiently large number of particles is counted. The relative uncertainty in such a measurement is given by $\Delta z = 1/z^{1/2}$, where *z* is the number of particles counted. Hence the time constant must be as small as possible, in order to allow a high rate of counting. As the current pulse in the point counter is approximately 10^8 times the primary pulse, a mechanical counting device can be operated with the help of moderate valve amplification.

THE ELECTROMETER COUNTER

The charge liberated with strongly ionizing particles is so large that it can be detected with a sensitive electrometer; one α -particle from polonium, for example, produces about 200 000 ion-pairs. After K. W. F. Kohlrausch and E. v. Schweidler, in 1912, had observed the charge by jerks of a string electrometer by α -particles, G. Hoffmann [3] provided, in the same year, his Duantelectrometer. With this it was really possible to measure the ionization produced by single α -particles and protons. A general application of this method has, however, been hindered by the fact that it demands an intricate and costly instrument, and because only a few particles can be counted per minute, owing to the inherent inertia of the electrometer.

THE CHAMBER COUNTER

The problem of detecting particles directly through their primary ionization was meanwhile attacked from a different direction. Work with valve circuits in combination with the point counter [4] led the present author to the idea of avoiding the point discharge and of amplifying the primary ionization of the α -particles to such an extent that they could be directly recorded. It was actually possible, by using four amplifying valves, to obtain clicks from a loudspeaker [5]. Figure 3 shows, diagrammatically, the layout of this counter, which consists of a combination of a small ionization chamber with an amplifying valve of specially high grid-insulation (electrometer valve). If an α -particle enters through O, the electrode, and hence the grid, receive a minute charge; this alters the anode current of the valve. The pulse is next amplified by a linear amplifier, to enable it to operate a recording circuit. This amplification needs to be much higher than that for the proportional and point counters; it must be about 10^6 . The counter is correspondingly more sensitive to disturbance, and requires particular protection from vibration and noise. There is also always a certain background, arising from the statistical variations of the grid current. The resolution-time is very short, since the ions discharge rapidly in the strong field (10 000 volts/cm). As above, it is measured by the time constant CR , but this can be made very small.

With these counters, α -particles and protons can be recorded without interference from β - and γ -particles present at the same time. The first photographs of records made by such particles [5], obtained by means of an oscilloscope, are reproduced in figure 10. The new method was soon adopted in several laboratories, and Rutherford

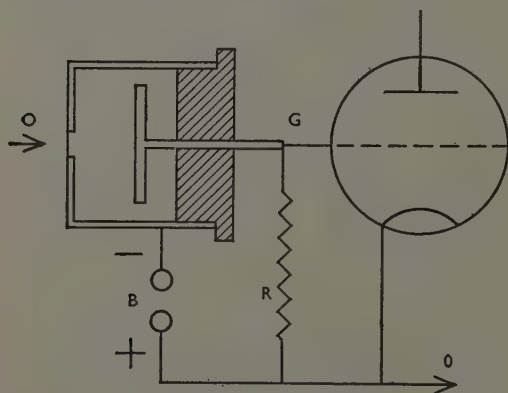


FIGURE 3 - Chamber counter.

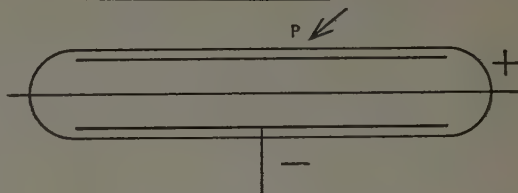


FIGURE 4 - Geiger-Müller counter.

and his collaborators published several papers on it; they called the instrument either a valve counter or a chamber counter. Unfortunately, the most diverse terms have since been applied to it, such as valve electrometer, Greinacher counter, ionization chamber with proportional amplifier, or simply proportional counter; the latter is an unfortunate term, since it had already been used for the multiplication counter. Rutherford's short and apposite name, chamber counter, is to be preferred.

The chamber counter has proved to be an indispensable adjunct to nuclear research. It can be used for the detection not only of α -particles and protons, but also of neutrons, which do not themselves produce ionization. If the chamber is filled with gaseous boron trifluoride, the B^{10} isotope may be transformed by collision with neutrons; this process is accompanied by emission of an α -particle, which is then counted. If fast neutrons have to be detected, a hydrogen-containing substance, such as polythene, is brought into the chamber; from such substances protons are ejected by recoil. The manufacture of high-efficiency chamber counter equipment is no longer a problem, and it may be bought ready for use.

THE GEIGER-MÜLLER COUNTER

Up to 1928 the point counter had to be used for the counting of β - and γ -rays. In that year H. Geiger and W. Müller [6] announced a considerably improved counter; the design (figure 4) is similar to that of the multiplication counter. The wire, however, is very thin, and the metal cylinder is sealed into a glass envelope. The counting process is similar to that in the point counter; instead of a point discharge, a corona discharge is obtained. The particle can enter at any point P, because the sensitive volume extends over practically the whole tube. While originally Geiger and Müller thought that counting could be done only if the wire is covered with a thin insulating film, H. Kniepkamp showed that the counter works even with bare wire. Usually a fine tungsten wire is used, which is baked to outgas and purify it.

For convenience in heating the tube, counters are made (following a suggestion made by R. Maze) without internal metal cathodes, but with an external conducting coating on the glass envelope. Commercial, and therefore not entirely pure, argon is generally used to fill the counters, at a pressure of about 80 cm of mercury. The negative voltage applied to the tube is about 1000 volts.

Since the corona discharge always forms along the whole of the wire, the amplitude of the pulses is always the same, regardless of whether strongly ionizing α -particles or very weakly ionizing mesons are measured. In the exceptional case of α -particles entering the tube at right angles, up to 50 times greater pulses are obtained (P. Huber and E. Baldinger, 1947).

A new stage in the development of the Geiger-Müller counter was reached with the discovery by A. Trost [7] that, by admixing with the argon gases whose molecules contain four or more atoms, 'self-quenching' counters can be made. In the usual counter a high leak-resistance has to be provided to ensure that even after discharge of the positive ions—that is to say, after the disappearance of the space-charge—the potential will fall to below the discharge potential. Such a resistance is not required with the self-quenching type. Here the discharge process is permanently interrupted even after the discharge of the electron avalanche, i.e. after about 10^{-6} sec; such counters are said to be 'fast.' The whole electrical process, however, including the drift of the positive ions, is in no way quicker than usual. However, the time constants of such counters can be reduced by using a smaller resistance R , and so the speed of recording can be increased. By suitable valve circuits, however, the same resolution can be attained even with ordinary counters. Many workers, such as E. Baldinger, P. Huber, S. A. Korff, C. G. and D. D. Montgomery, and H. G. Stever, have concerned themselves with the not altogether simple conditions existing in these counters, but only a few fundamentals can be discussed here.

Two separate phases in the counting process must be distinguished: the dead time, during which no second particle is indicated, and the recovery time, at the beginning of which the pulses are counted at low intensity and at the end of which they are counted again at full intensity. Both intervals are of the order of 10^{-4} sec. As E. Greiner showed for the first time, the photo-effect plays a decisive part in the discharge process. If an electron avalanche is formed at any point in

a counter filled with argon—and therefore not of the self-quenching type—it excites the argon atom itself to emission of ultra-violet radiation, which releases photo-electrons from the wall. In this way electron avalanches are initiated on all parts of the wire, until the latter is surrounded by a positive ionic sheath which screens the field. The discharge is then quenched, and the ions travel to the wall of the tube, from which they detach electrons, giving up their energy in the process. If at this stage the transferred charge has already leaked away through the resistance R these electrons now induce a second discharge. A permanent disruptive discharge would then arise; to quench it, the resistance must be sufficiently high. But if vapour such as that of alcohol is mixed with the argon, the ultra-violet radiation, even if it is emitted during the first electron avalanche, is absorbed by the vapour after traversing only a few millimetres of it, and does not reach the tube wall. This absorption is accompanied by the ejection of electrons from the vapour molecules in the immediate neighbourhood of the avalanche, since the vapour is more easily ionized than argon is. The discharge therefore spreads along the wire (at the rate of 10^6 to 10^7 cm/sec) and positive ions again drift to the wall, but now they consist almost entirely of ionized vapour molecules. As these are not able to detach electrons from the wall, no further discharge occurs, even if the applied voltage is fully effective. Instead, the vapour molecules decompose, and this decomposition sets a limit to the life of such self-quenching tubes; nevertheless, they will measure up to 10^8 and more pulses without trouble. According to E. Fünfer and H. Neuert, counters filled with a pure vapour such as that of methylal, $\text{CH}_2(\text{OCH}_3)_2$, show a good quenching action.

If a voltage below the 'Geiger-Müller threshold' is applied to such a counter, it operates as a proportional counter, and no ionic sheath is formed, nor are electrons liberated at the tube wall as a result of the positive ions arriving there.

Counters are commercially available in different patterns and sizes, down to less than 1 cm long and 2–3 mm diameter. Complete measuring equipments incorporating Geiger-Müller counters are manufactured, ranging from impressive laboratory instruments to compact control and ore-prospecting outfits. Figure 7 shows such a portable instrument. The counter is firmly clamped to the handle, and with it either γ -rays alone, or both γ - and β -rays, can be measured, according to the position of a rotatable diaphragm. Beside this apparatus

lies another counter, which counts α -particles if the cap is removed. The counting speed can be as high as 100 000 per minute.

COUNTING EQUIPMENT

The circuits into which Geiger-Müller counters are inserted come within the province of electronics and can be dealt with only briefly here. In general, the counter is connected with a coupling circuit, which executes a quenching action on 'slow' counters; to this are connected an amplifier and finally a recorder. As mechanical counters generally cannot cope with more than 500 pulses per second, scalars are employed, permitting far higher counting speeds at a resolution of 10^{-6} sec. In these devices a circuit is employed such that only every second pulse is recorded (hence the term 'scale of two'). If this pulse is fed to a second scalar, then only every fourth pulse is counted. If n scalars are connected in series, only one in every 2^n particles will be counted. The response of each stage in the cascade of scalars is indicated by a neon lamp. If, for instance, the lamps in circuits 1, 3, 4, 7, and 8 light up, the corresponding number of pulses is $1 + 8 + 16 + 128 + 256 = 409$. Scalars working on a scale of ten have also been made.

If the number of particles per second is to be determined, a determination of time is evidently involved; this can be avoided by employing an instrument known as a rate-meter (figure 7). A large-capacitance condenser is included in the recording circuit of the counter, connected across a current-measuring instrument. This indicates the electrical current carried by the output signal.

If it is desired to count only the pulses which exceed a certain magnitude, a discriminator is employed. This is, in principle, a valve whose grid is made so negative that only positive signals of a certain magnitude can pass the barrier. By using a number of such discriminators, which count either pulses of different magnitude or different pulse intervals—for example, by sorting the pulses according to size—the pulse distribution can be determined (pulse spectrometer).

Many problems of nuclear physics require a decision as to whether two or more events are simultaneous. To solve this there are 'coincidence' circuits. W. Bothe was responsible for the first, though that developed by B. Rossi is much used nowadays. With the aid of delayed coincidences, intervals of time between two events down to 10^{-9} sec can be detected. If a pulse-reversal stage is inserted into the circuit, an 'anti-coincidence' cir-

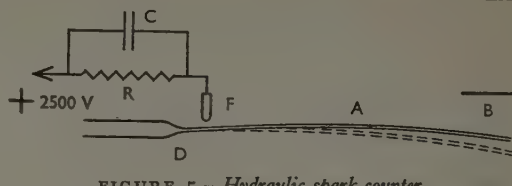


FIGURE 5—Hydraulic spark counter.

cuit is obtained, which indicates when one event occurs independently of another.

THE SPARK COUNTER

The first spark counter, which was described by the present writer in 1934 [8], was the hydraulic model. Figure 5 shows one suitable for a demonstration experiment. A jet of water about 1 mm thick, and coherent for about 20 cm, flows out through the nozzle D. An iron rod F is set about 1 mm away. A positive voltage of about 2500 volts is applied to it, such that there is no spontaneous spark discharge. The resistance is about 10^8 to 10^9 ohms and the capacitance about 100 picofarads. Any spark released by α - or β -particles or γ -rays causes a drop in the potential of F. The attraction on the water jet decreases for a moment, so that the jet executes a jerky movement, giving rise to a sharp sound from the metal can B. If we imagine a recording instrument to take records of the point A of the water jet, photographs such as that shown in figure 11 would be obtained. Sparks are produced by ultra-violet radiation as well as by α - and β -particles and γ -rays; for this purpose electrons released photo-electrically from water suffice. The hydraulic spark counter is a quite general means of measuring the elementary photo-effect on the surfaces of pure liquids.

In the usual spark counter [9] there are two metal electrodes, which can be of the most diverse

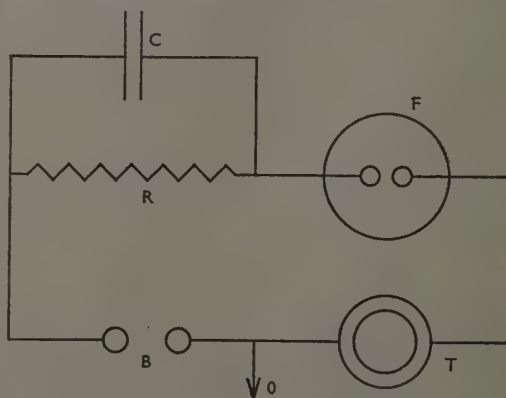


FIGURE 6—Spark counter based on combination of two spheres.



FIGURE 7 - *Geiger counting instrument (rate-meter).*



FIGURE 8 - *Spark sequence; lower series magnified.*



FIGURE 10 - *The first recording made with a chamber counter. Above, protons; below, α -particles.*

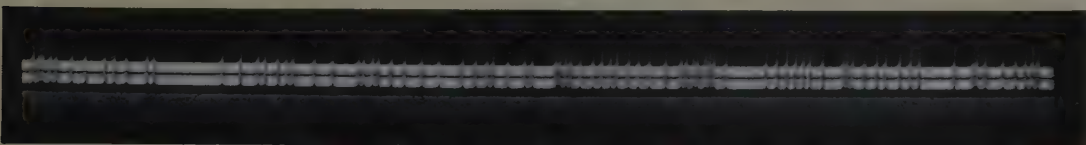


FIGURE 11 - *Recording made with an hydraulic spark counter.*

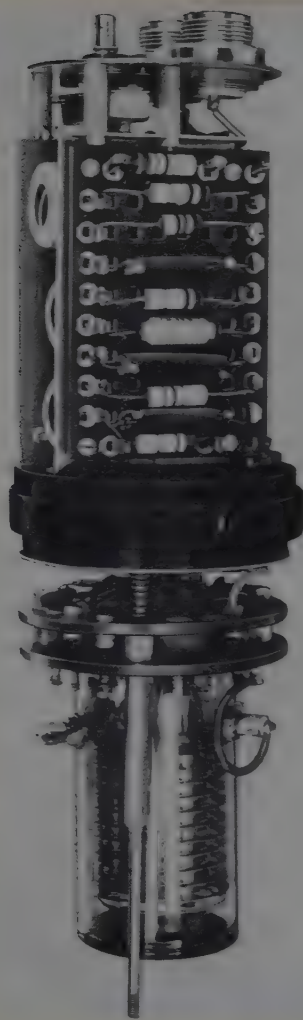


FIGURE 9 - *Scintillation counter (interior): assembly of crystal, multiplier, and amplifier. Above, amplifier; below, multiplier with crystal.*

NOTE. Figures 7 and 9 have been supplied by Messrs Tracerlab, Boston, U.S.A., and Ekco Electronics Limited, Southend-on-Sea, respectively.

forms, set about 1 mm apart. Figure 6 shows a combination of two spheres. The current pulses obtained here are so large that they can be detected directly with a galvanometer, neon tube, or loud-speaker. Usually no indicator is inserted into the circuit; either the spark is photographed (figure 8 shows a record so obtained) or the waves propagated from the sparks are picked up by a radio receiver. Audible spark cracks are obtainable if the electrodes are set at larger distances.

It is interesting that below the voltage necessary for counting β - and γ -rays there is a further range—some 100–200 volts—where only α -particles are counted. In the upper region all particles produce pulses of equal magnitude, whatever the primary ionization. This indicates the same discharge mechanism in all cases: collision ionization by the primary electrons and release of electrons from the cathode by the resulting ultra-violet radiation and by secondary emission on impact of positive ions. There are, however, still unsolved problems relative to the spark process. For example, sparks can be released even without irradiation. It is sufficient, for instance, to bring a piece of camphor into the neighbourhood of a spark gap, ready for flash-over, for a spark sequence to occur; this dies away when the camphor is removed.

Since the duration of a spark is brief (as little as 10^{-9} sec), the spark counter has been further developed as the plate counter [10]. Two metal plates are set 1–2 mm apart in a glass vessel, filled with argon-alcohol at about half an atmosphere pressure, as in the Geiger-Müller counter. Unlike the normal spark counter, it gives a plateau. The sensitive volume, extending over the whole intermediate space, is also considerably larger.

W. Y. Chang and S. Rosenblum [11] have reported an interesting method of operating the spark counter. The arrangement consists of a thin wire, stretched at a height of about 1–2 mm

above a metal plate. A positive potential of about 3000–5000 volts is applied to it, high enough for a continuous corona current of about 1 milliamp to flow. If an α -particle passes the wire, a directly visible and audible spark is produced. To enlarge the counting volume, counters have been made with many parallel wires in 'guitar and harp' forms. The corona spark counter, which does not respond to β -particles or γ -rays, is the only such instrument which operates with a steady current.

THE ELECTRON MULTIPLIER

The counters so far described have the common feature of being based on gas ionization. This is not so with some newer methods, which are based on electron multipliers. Figure 12 shows the essentials of such a device. A number of metal electrodes are sealed into an evacuated glass envelope. A potential of 1000 volts or more is applied between the first and the last electrodes, and this potential is divided between the various electrodes so that there is always the same difference—say 100–200 volts—between two successive electrodes. Electrode 1 has a photo-electric coating such as caesium oxide. Electrons released by incident light are accelerated to electrode 2, from which they release secondary electrons, which travel to electrode 3, and there again multiply themselves by secondary emission. There is thus a progressive multiplication. If the multiplication is threefold between any two electrodes, and there are altogether 13, the total multiplication is 3^{12} ; with 16 electrodes a factor of 10^9 can be reached.

The principle of the electron multiplier was published as far back as 1923 by I. Slepian. However, it was not until 1936 that V. K. Zworykin [12] brought it, by good focusing of the electron beam, to the efficiency necessary for technical use. The multiplier, originally developed for television, thus became available as a perfected instrument for nuclear physics. Reports on the measurement of α - and β -particles and γ -rays with multipliers, with and without photo-electric layers, appeared as early as 1938–9 [13]. The resolution of these counters is 10^{-8} sec, higher than with Geiger-Müller counters because the process occurs in a vacuum. Nevertheless, the new method did not at first find very wide use.

SCINTILLATION COUNTERS

In 1947 H. Kallmann proved [14] that the flashes of light produced when α -particles strike zinc blende can be recorded with a photo-multiplier. A scintillation counter based on this

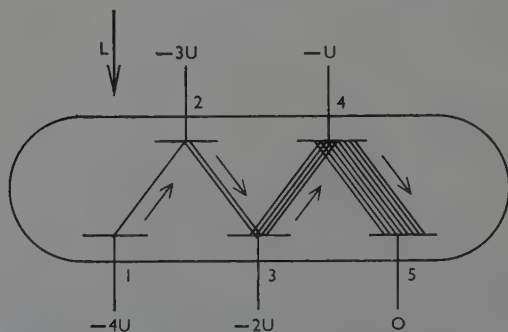


FIGURE 12—Principle of the electron multiplier.

principle consists of a multiplier, before whose input plate a crystal is placed. Even the scarcely visible flashes from β - and γ -rays can be counted. The crystal used must give out a considerable flash, and the flash must decay rapidly; in commercial scintillation counters a sodium iodide crystal activated with thallium is used. In this way an efficiency for Röntgen and γ -rays considerably above that of Geiger-Müller counters can be attained. Anthracene is also suitable as material for the crystal, because of its small decay time; stilbene gives even shorter light flashes (10^{-8} sec and less). Liquids too are used.

These counters must be carefully screened from light. Even then there is a residual background of natural signals, mainly because of thermal emission from the photo-cathode. This can be reduced by cooling, or, better, by using for the electrodes a material for which the work function is high, for example nickel with a thin covering of beryllium.

The non-homogeneity of the pulses is countered by insertion of a discriminator, which suppresses small pulses. Because of the high resolving power of the scintillation counter (down to 10^{-9} sec) it is of importance for timing nuclear processes. Electrostatically focused multipliers must be protected from magnetic effects, and it is therefore often desirable to separate the multiplier from the crystal. This can be very simply done by interposition of a light-guide (for example of Perspex) which transports the light by total internal reflection. If desired, the counting head can be provided with a lead hood or collimator, with a channel-shaped opening. For medical and biological purposes there already exist compact assemblies which contain an amplifier in addition to crystal and multiplier, and which can be directly connected to a scaler; figure 9 shows an example of such a set-up.

THE CRYSTAL COUNTER

Many crystals have the property of displaying an enhanced conductivity when particles are incident upon them. If such a crystal is brought between two metallic sheets to which a potential difference is applied, current pulses are produced by α - and β -particles and by γ -rays, and these can be recorded after even moderate amplification. P. J. van Heerden [15] has investigated this phenomenon, known since 1941, and has used a silver chloride crystal as a basis for a crystal counter. These counters are slightly older than the scintillation counters, but have not been able to command the same attention, although their resolving power is just as good. There is no lack of crystals—for example, diamond, cadmium sulphide, thallium bromide, germanium—but some complications are encountered in using them. Many crystals, such as silver chloride, must first be made insulating, which is done by cooling. Different counters of the same design show different counting action, and this action can even differ from place to place on the same crystal. The pulses are correspondingly non-homogeneous. This is related to the fact that electronic conduction is influenced by crystal lattice defects, which are irregularly distributed. Finally, interference is caused by polarization effects.

THE LIQUID COUNTER

Liquids also can show conductivity effects, but observations on this phenomenon are as yet very few. N. Davidson and A. E. Larsh [16] reported in 1948 that when liquid argon is used, counting pulses are obtained from α -particles. However, in the state of development they have at present reached, such counters cannot be said to be of any practical importance.

REFERENCES

- [1] RUTHERFORD, E. and GEIGER, H. *Proc. roy. Soc., A*, **81**, 141, 1908.
Idem. Phys. Z., **10**, 1, 1909.
- [2] GEIGER, H. *Verh. dtsch. phys. Ges.*, **15**, 534, 1913.
Idem. Phys. Z., **14**, 1129, 1913.
- [3] HOFFMANN, G. *Phys. Z.*, **13**, 481, 1929, 1912.
HOFFMANN, G. and POSE, H. *Z. Phys.*, **56**, 405, 1929.
- [4] GREINACHER, H. *Ibid.*, **23**, 361, 1924.
- [5] *Idem. Ibid.*, **36**, 364, 1926; **44**, 319, 1927.
- [6] GEIGER, H. and MÜLLER, W. *Phys. Z.*, **29**, 839, 1928; **30**, 489, 1929.
- [7] TROST, A. *Z. Phys.*, **105**, 399, 1937; Prelim. Comm., **36**, 801, 1935.
- [8] GREINACHER, H. *Helv. phys. acta*, **7**, 360, 514, 1934.
- [9] *Idem. Ibid.*, **9**, 590, 1936.
Idem. Z. tech. Phys., **16**, 65, 1935.
- [10] MADANSKY, L. and PIDG, R. W. *Phys. Rev.*, **73**, 1215, 1948.
KEUFFEL, J. W. *Ibid.*, **73**, 531, 1948.
- [11] CHANG, W. Y. and ROSENBLUM, S. *Ibid.*, **67**, 222, 1945.
- [12] ZWORYKIN, V. K. *Proc. Inst. Radio Engrs, N.Y.*, **24**, 351, 1936.
- [13] BAY, Z. *Nature, Lond.*, **141**, 284, 1011, 1938.
- [14] KALLMANN, H. *Natur u. Tech., Berl.*, July 1947.
BROSER, J. and KALLMANN, H. *Z. Naturf.*, **2a**, 439, 1947.
- [15] VAN HEERDEN, P. J. Thesis, Utrecht. 1945.
- [16] DAVIDSON, N. and LARSH, A. E. *Phys. Rev.*, **74**, 220, 1948.

Toxins and plant diseases

E. GÄUMANN

The micro-organisms responsible for disease act by virtue of the toxins they produce. Although the fundamental importance of this principle is recognized in medicine, and although there has been considerable study of the toxins produced by pathogenic bacteria, its implications in plant pathology are only beginning to be appreciated. Nevertheless, progress has been made towards identifying the toxins responsible for a variety of plant diseases. From such knowledge may come novel methods of treating infected crops.

Micro-organisms are pathogenic only if they are toxigenic; in other words, the agents responsible for diseases can damage their hosts only if they form toxins—microbial poisons—that penetrate into the host's tissues. This rather sweeping statement applies to both human and veterinary medicine, and to plant pathology. Hence in both fields an important question of pathogenesis is that concerning the physical action of the parasite on the host. What are the chemical nature and the mode of action of the substances secreted by the infective organism into the host, causing the latter to become diseased?

The extent to which such a question can be answered differs greatly in the medical and the plant pathological fields. Botanically, study of the problem of the genesis of disease is still new; up to the present, therefore, research has been directed to the acute provokers of disease which kill the tissues of their hosts. The biologically far more interesting groups of infective agents—those which do not damage their hosts in such a crude way, but only upset the normal tenor of their existence and stimulate them to greater neoplastic growth—have not so far been studied.

An interesting example of research in these more difficult fields is given by the tumours (crown galls) which are produced in many plants by *Bacterium tumefaciens* (figure 10). It is known that the development of these galls occurs in two stages: an alternative phase and a period of neoplastic growth. During the alternative phase the host-cells attacked by the irritant are set free from their internal connections and converted into potential tumour cells. These are not independently able to develop further as actual tumour cells; this can occur only in a second stage, in which the concentration of growth-promoting substance present in them increases. The additional quantity of growth-promoting substance is not, however, contributed by the parasite itself;

the latter induces the production of growth-promoting substance by the host.

Thus at least two toxins must be effective during pathogenesis of *B. tumefaciens* tumours: an alternative toxin, which causes the fully grown vegetative cells to become potential tumour cells, and a second toxin, which stimulates the host to abnormal production of growth-factor and thereby to neoplastic growth. The alternative toxin is of exceptional biological interest, as it is possibly comparable, *mutatis mutandis*, with carcinogenic substances in human pathology.

Both toxins, or groups of toxins, have so far escaped identification. The relevant alternative processes are biologically so subtle that it has not yet been possible to reveal them by a simple test, such as is necessary for routine assays in the chemical isolation of a substance. On account of these technical difficulties, research workers in botany have so far obtained results only with parasites which cause in the host more or less lethal damage, such as local necrosis. Results may be discussed under two headings: toxigenic parasites having respectively (a) short-range and (b) long-range action.

TOXIGENIC PARASITES WITH SHORT-RANGE ACTION

In parasites of this first group the toxins operate directly on the tissue surrounding the focus of infection. Not only the parasite but also the toxin it produces, and the damage done are localized; the site of disease coincides very largely with the site of infection.

In medicine this type of disease is rare. One of the few examples (apart from certain skin diseases) is provided by *Clostridium histolyticum*, a wound parasite which causes necrosis at its point of attack, and dissolves the tissue down to the skeleton. In plants, on the other hand, numerous diseases are of this type—for example, many 'leaf-spot'

diseases. Two examples will be described here, the wildfire disease of tobacco and the early blight (dry-spot disease) of potatoes.

Wildfire in tobacco is caused by a bacterium, *Pseudomonas tabaci*, and gets its name from the characteristics of its incidence. It appears suddenly, and spreads rapidly through the whole crop; in some cases the harvest can be totally ruined. In rainy weather the bacteria penetrate through the openings of stomatal fissures into the interiors of leaves. After a few days the focus is necrotic and brown, and is surrounded by a bright green, chlorotic halo 1–2 cm wide (similar to that shown in figure 11), in which the chlorophyll suffers serious damage. This areola is free from bacteria; it is caused by traces of a substance called tabtoxinin, formed by the parasite in the central focus of infection, from which it diffuses into the surrounding tissue. Chemically, tabtoxinin is an α -amino acid, a diamino-hydroxypimelic acid having the formula $C_7H_{14}O_5N_2$ [1]; closely related compounds are produced also by the bacteria that cause diphtheria and tuberculosis. Tabtoxinin is extraordinarily poisonous to the tissue of tobacco leaves and even 0.05 μ g produces necrosis, surrounded by a chlorotic halo (figure 11).

To work out the mode of action of this toxin, Braun [2] used as a test organism the unicellular green alga *Chlorella vulgaris*. The rate of growth of *Chlorella* cultures is reduced by *Pseudomonas* toxin. If liver extract is added to such retarded cultures, tabtoxinin is not deactivated, but its retarding effect is eliminated; thus the liver extract apparently contains some factor, essential for *Chlorella*, that is rendered inaccessible by the tabtoxinin.

It was finally recognized that *l*-methionine is the factor which suppresses the toxic action of wildfire bacteria. The decisive part of the action of tabtoxinin consists in preventing *Chlorella* from using *l*-methionine that it has itself synthesized. This explanation is supported by the fact that a synthetic antagonist of methionine, methionine sulphoximine, causes the same symptoms in tobacco leaves as does *Pseudomonas* toxin.

Tabtoxinin is non-specific both in its host-range, for it affects various plants, and in the tissues it attacks, for it damages various tissues of the tobacco plant. On the other hand, it is highly specific in its point of attack inside the host cells, for there it blocks a clearly defined link in the metabolic chain.

Dry-spot disease (early blight) of the leaves of

various Solanaceae, such as potatoes and tobacco (figure 1), is caused by the fungus *Alternaria solani* (figure 9). The host's tissue reacts to the diffusion of the metabolic products of this fungus, forming darkly coloured, suberized barrier-tissues. In circumstances favourable to the fungus these barrier zones are, however, again pierced by the parasite, so that in time there forms round the focus a whole series of concentric barriers of suberized defensive tissue (figure 8).

The aetiology of this disease is much more complicated than that of wildfire, as can be seen by considering figures 8 and 11. In wildfire there is a simple tissue-poisoning, whereas with early blight there is a complicated and obscure interplay of actions and reactions. Since the host is the same in both cases, the different reactions must be determined by differences in the nature of the parasite.

Alternaria solani forms several toxins, of which two have so far been isolated: alternaric acid [3] and alternarin [4]. Both are nitrogen-free substances, and their chemical constitutions are still unknown. The formula of alternaric acid is $C_{21}H_{30}O_8$ and its molecular weight 410.

The nature of the action of these two toxins on the host, and the nature of their interaction in the host, are not known. They are apparently even less specific in their action than tabtoxinin is. While the latter attacks at one point in the metabolic chain, alternaric acid, for instance, is capable of upsetting several metabolic mechanisms in the host; for example, it interferes very seriously with the osmotic properties of the host cells. Corresponding to this smaller specificity, alternaric acid is less toxic than tabtoxinin; nevertheless, it produces fatal effects at a dose-rate of 220 μ g per kg of live-weight of the host [5].

These two leaf-spot diseases cause only local necroses in the host, and, in contrast to *Clostridium histolyticum*, quoted above, do not lead to any histolysis such as is known in some other plant diseases, e.g. certain infections of trees. Figures 6 and 7 show two samples of wood from the trunk of an oak suffering from a fungal disease. The causative agent, *Stereum frustulosum*, has penetrated into the interior of the trunk through wounds and has dissolved out the protopectin and lignin from the woody tissues, leaving the cellulose untouched. The white parts in figure 6 and the white fibres in figure 7 are thus not threads of fungus, but woody fibres, freed from their surroundings by the lytic enzymes of the parasite so that the white cellulose is revealed like purified cotton wool. The



FIGURE 1 — Early blight of potato leaf, caused by the fungus *Alternaria solani*. (After R. Maag.) ($\times \frac{1}{2}$)



FIGURE 2 — Wilt breakdown of a tomato plant under the influence of lycomarasmin. The leaves are withered, but the petioles and stems are still turgid. ($\times \frac{1}{2}$)

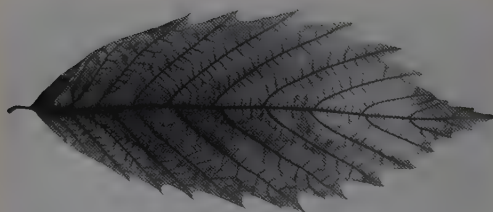


FIGURE 3 — Necrosis of the vascular bundles of the leaves of Spanish chestnut (*Castanea sativa*), caused by the wilt toxin diaporthin, a product of *Endothia parasitica*. ($\times \frac{1}{3}$)



FIGURE 4 — Illustration of the principal damage to tomato leaves by lycomarasmin; note necroses of the intercostal regions, the leaf veins remaining unattacked [14]. ($\times \frac{3}{4}$)



FIGURE 5 — Main symptoms of patulin wilt: the stems and petioles of tomato plants lose their turgor, while the leaf blades at first remain intact. ($\times \frac{1}{4}$)

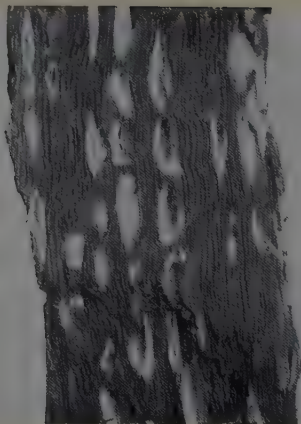


FIGURE 6—Early stage in an infectious disease of the trunk of an oak, caused by the fungus *Stereum frustulosum*. Characteristic cavities have been formed in the woody tissue. (Natural size)



FIGURE 7—Late stage in the infectious disease of an oak trunk, caused by *Stereum frustulosum*. Histolysis has caused complete defibrination of the woody tissue. (Natural size)

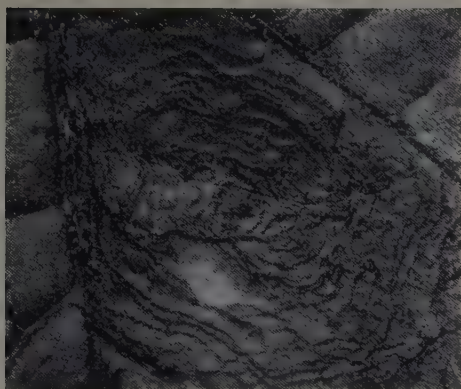


FIGURE 8—Detail of early blight on a potato leaf, caused by *Alternaria solani*. The focus of infection is surrounded by concentric, suberized, anti-toxic demarcation zones. (After R. Maag.) ($\times 10$)



FIGURE 9—Conidia of *Alternaria solani*, the cause of early blight on the leaves of tobacco and potato plants [4]. ($\times 160$)



FIGURE 10—Tumour with root formation on a stalk of *Impatiens balsamina*, produced by *Bacterium tumefaciens* [13]. ($\times \frac{1}{2}$)

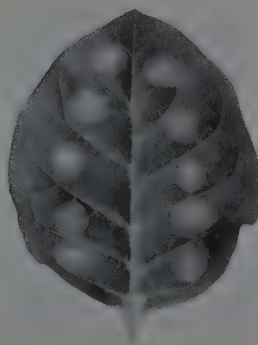


FIGURE 11—Chlorotic damage produced in a tobacco leaf by traces of tab-toxinin. (After A. C. Braun.) ($\times \frac{1}{5}$)

parasite thus produces in the woody tissues first the characteristic cavities of figure 6 and finally the general breakdown of tissue shown in figure 7.

TOXIGENIC PARASITES WITH LONG-RANGE ACTION

In medicine, tetanus is the standard example of this second group: the pathogenic bacterium develops anaerobically in a peripheral wound and its toxin penetrates into the host tissue, diffusing along the nerve tracks to the brain and there producing the characteristic paralysis of the motor system. The site of the disease and the appearance of symptoms are thus remote from the focus, and the generic connection between these two elements of the disease was recognized only after decades of scientific research.

In the vegetable world, infectious diseases in which there is separation of the site of infection and the area in which the symptoms appear are represented by a series of economically important 'wilt' diseases. Thus *Fusarium cubense* causes, throughout the tropics, the Panama disease of bananas; *Fusarium vasinfectum* is a wilt disease of cotton plants in most regions where they are cultivated; and *Endothia parasitica* is responsible for the death of many chestnut trees in the northern hemisphere.

In all these diseases, the parasite attacks a particular site—for example, the roots or shoots or stems of the host—and transmits its toxins into the host's vascular system. The toxins are transported into the foliage and, in certain circumstances, may cause such a surprising collapse of the leaves that the corresponding disease of apricot trees in the valley of the Rhône has been dubbed 'apoplexy.' Apricot trees infected with a fungus of the *Valsa* group, not noticeable on the trunk, appear normal in the spring and bloom in the ordinary way. In June their crowns lose their turgor almost overnight through the action of the toxin, they wilt, and whole trees perish.

The study of these wilt diseases was begun on an economically less important representative, namely the wilt disease of tomatoes, caused by the fungus *Fusarium lycopersici*. The reason for this choice was that tomato plants can be easily cultivated throughout the year, in large numbers, in a glasshouse.

The parasite penetrates from the soil into the roots of the plants and grows far up into the stems. Its toxins cause a browning and necrosis of the vascular bundles of the stem (similar to the symptoms in leaves seen in figure 3) and characteristic

discoloration and necrosis of the leaves (figure 4).

Up to the present, four toxins have been isolated from *Fusarium lycopersici* grown *in vitro*. Two of these (pectase and vasin fuscarin) specifically produce the browning and necroses of the vascular bundles, and two others (lycomarasmin and fusaric acid) are mainly responsible for discoloration and necroses of foliage.

Pectase [6] is a pectin methyl esterase, produced by numerous parasitic fungi. Vasin fuscarin [7] is apparently a protein having enzymatic properties, but it has still not been isolated in the pure state. Lycomarasmin is a dipeptide having the formula $C_9H_{15}O_7N_3$ and molecular weight 277 [7]. Fusaric acid is a pyridine carboxylic acid with the formula $C_{10}H_{13}O_2N$ and molecular weight 179 [8].

Chemically, these four toxins belong to different groups. Their molecular weights are small compared with bacterial toxins well known in medicine (diphtheria toxin has molecular weight 72 000; botulinus toxin A, 900 000). This may be connected with the selective filter-action of the cell walls of plants. Solutions which rise into the plant shoots through the vascular bundles diffuse, after leaving these paths, within the cell walls and bathe the cell contents in the tissues from all sides. Hence the toxins, transported along with other dissolved substances, also bathe the protoplasts over their entire surfaces. Naturally, the toxins most active in the plant tissues are those which are capable of penetrating the submicroscopic spaces in the micellar felt of the cellulose walls; this means, in effect, toxins of relatively low molecular weight.

So far as present experience shows, human pathogenic bacteria exhibit a considerable specificity in respect of the toxins which can be extracted from them; thus tetanus toxin appears to be characteristic of the tetanus organism, diphtheria toxin of diphtheria bacteria, and so on. The active agents of plant wilt diseases are more primitive in this respect; that is, they are less specialized. Thus the fusaric acid mentioned above is produced not only by *Fusarium lycopersici*, but also by *Fusarium heterosporum*, which causes a disease in maize, rice, and sugar cane in eastern Asia; by *Gibberella fujikuroi*, the cause of the bakanae disease of rice in eastern Asia; by *Fusarium vasinfectum*, the cause of a wilt disease of cotton; and also by *Nectria cinnabarina*, the cause of red-spot disease in numerous shrubs and deciduous trees of the temperate zone. This substance is thus produced by various parasites on various hosts. This generality of toxin production suggests

that the toxins in question are produced by relatively simple reactions from widely occurring substances.

The wilt toxins do not act only on the specific host of the parasite that forms them. The range of plants sensitive to a particular toxin is considerably wider than the range of hosts of the toxin-producing parasite. Thus *Fusarium lycopersici* cannot attack the grape-vine (*Vitis vinifera*), but its toxins can produce the same sort of damage in the grape-vine as they do in the tomato. The natural resistance of the grape-vine to this parasite is thus not a reflection of any resistance to the toxin produced by it, but of a resistance to the parasite itself, which is unable to get a hold on this uncongenial host.

Do wilt toxins affect all tissues of the host uniformly? The answer is again in the negative. In plant wilt diseases, as in the human disease diphtheria, not only the sites of infection but also the organs attacked by the toxin or toxins are relatively specific. Wilt toxins act only on certain tissues of the host; they show a predilection for them—they are histotropic. Thus lycomarasmin passes through the stems, petioles, and leaf veins of tomato plants almost without causing any symptom; it produces its primary symptoms only in the intercostal fields of the leaves (the regions between the leaf veins, figure 4). On the other hand, vasinifuscarin damages only the vascular bundles of tomato plants (similar to that of the leaf veins in figure 3), leaving the tissues of the intercostal region intact.

The same predilection for certain tissues of the host is shown, however, by completely different toxins with an apparently completely different mode of action. Thus visually identical browning and necroses of the vascular bundles are produced by pectase, vasinifuscarin, fusaric acid at pH below 6.2, and by diaporthin, a toxin of *Endothia parasitica* [9]. Hence, in plant wilt diseases identity of the outwardly visible symptoms in a particular organ does not necessarily indicate identity of the causal toxins.

Compared with the short-range toxins mentioned earlier (tabtoxinin, alternaric acid), the wilt toxins so far known are only mildly poisonous; a dose of 150 mg of lycomarasmin or fusaric acid is required per kg of live-weight to produce definite damage to tomato shoots. The cause of this high threshold value is still unknown; possibly it is due to diffusional losses

resulting from adsorption or inactivation during transport, or something of the sort.

As mentioned earlier, all agents causing wilt diseases form several toxins, and each of these interferes, so far as we know at present, with several mechanisms in the host. The mode of action of the wilt toxins is thus less specific than that of the tabtoxinin previously described. The combined action of wilt toxins in the host is determined, however, not only by their chemical effects, but by the sequence and extent of their production by the parasite. We still know little about any of these factors.

The main symptom of the wilt diseases is the visible wilting, which makes the attacked plant become flabby. It was at first supposed that this was connected with a pathological loss of water from the attacked plant, similar to the physiological wilting which follows on a pathological deficiency of water.

However, this simple interpretation has not withstood tests made with individual toxins, for, depending on the toxin investigated, either the stems and petioles (figure 5, toxin patulin) or mainly the leaf blades (figure 2, toxin lycomarasmin) are affected. Thus the impairment of the turgor is specific for certain organs and varies according to the particular toxin involved, and is not the result of simple water deficiency.

Moreover, although the wilt process may be accompanied by a pathological water-loss, this is not necessarily so. Pathological water-loss is thus only an accompanying symptom. If a tomato plant is allowed to take up a wilt toxin in an atmosphere of 94 per cent relative humidity its transpiration is at a minimum on account of the

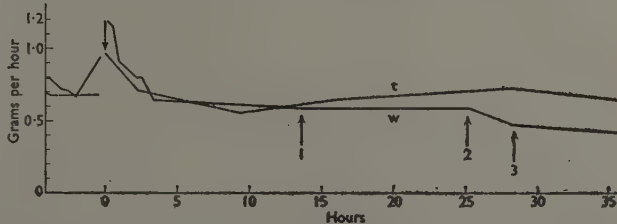


FIGURE 12—Graphs illustrating wilt of a tomato plant produced by toxin without loss of water. This occurs if the wilt test is carried out in an atmosphere almost saturated with water vapour. The experimental plant shoot was inserted into the toxin solution at the time marked with the arrow. The abscissae indicate the hours from the start of the experiment; the ordinates indicate water uptake (w) or transpiration (t) of the whole plant shoot in grams per hour. At (1) the leaves are no longer completely turgid, but slightly curled up. At (2) the growing tip is hanging down and the two lowest leaves are flabby and hanging from the petiole. At (3) all leaves are flabby and show considerable wilt [10].

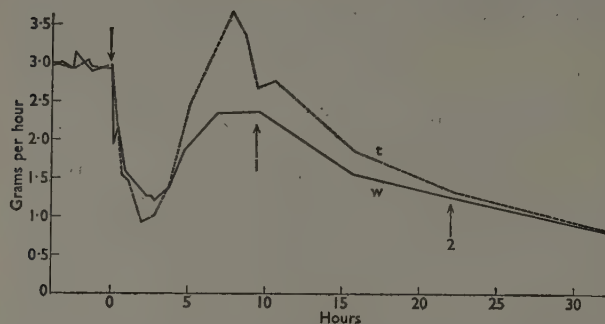


FIGURE 13—Disturbance of the water balance of a tomato plant as a result of lycoramin; atmospheric humidity normal. Details as for figure 12. At (1) the lowest leaf shows the first signs of wilt. At (2) the whole plant has wilted [11].

high humidity (figure 12); nevertheless, it begins to wilt after 14 hours [10], and after 30 hours it is completely flabby.

There is a similar independence of wilt effect and water loss at normal humidities. Figure 13 illustrates the behaviour of some experimental plants which have responded to the application of lycoramin by very suddenly reducing, and then by exceeding, their normal water balance. About 10 hours after the beginning of the experiment the first signs of wilt appear, although at this time the tomato plants have lost only about 6 per cent of their water store. Sound plants can tolerate a water loss of about 50 per cent without visible symptoms. The wilt effect is thus not a matter of a pathological loss of water from the damaged plant, but of an interference with the directional permeability (semi-permeability) of its protoplasts, and thus of an interference with

the osmotic requirements necessary for turgor.

The mechanisms which lead to such impairment of the semi-permeability of the plasma membranes are still unknown. Several wilt toxins, including lycoramin and fusaric acid, can form chelate compounds with, and thus block, metal ions in the host that are essential to life: they can thus act as antimetabolites [12]. However, the relationship of this process to disturbances in permeability are still uncertain.

Moreover, the fungi causing wilt diseases form—together with the true wilt toxins, which produce the visual wilt of the attacked plants—still other toxins, which produce, for instance, local chlorosis (damage to chlorophyll), stiffenings (rigidification of certain organs), necroses, and so on, all symptoms that are superimposed on the visible wilt. We are therefore a long way from a thorough understanding of the pathogenesis of wilt diseases.

THE THERAPY OF INFECTIOUS DISEASES OF PLANTS

Knowledge of the nature of toxins produced by parasites opens up new possibilities for combating the corresponding infectious diseases. It is possible that eventually plant diseases may be dealt with not by attacking the parasite itself, but by inactivating its toxins by allowing the attacked plant to take up substances which would render them harmless; this is already the pattern of medical treatment for diphtheria.

REFERENCES

- [1] WOOLLEY, D. W., SCHAFFNER, G., and BRAUN, A. C. *J. biol. Chem.*, **198**, 807, 1952.
- [2] BRAUN, A. C. *Proc. nat. Acad. Sci., Wash.*, **36**, 423, 1950.
- [3] BRIAN, P. W., ELSON, G. W., HEMMING, H. G., and WRIGHT, J. M., *Ann. appl. Biol.*, **39**, 308, 1952.
- BRIAN, P. W. Personal communications.
- [4] DARPOUX, H., FAIVRE-AMIOT, A., RIDE, M., and ROUX, L. *Ann. Épiphyt.*, **4**, 423, 1952.
- [5] GÄUMANN, E., NAEF-ROTH, S., REUSSER, P., and AMMANN, A. *Phytopath. Z.*, **19**, 160, 1952.
- [6] WINSTEAD, N. N. and WALKER, J. C. *Phytopathology*, **44**, 153, 1954.
- [7] PLATTNER, P. A., CLAUSON-KAAS, N., BOLLER, A., and NAGER, U. *Helv. chim. acta*, **31**, 860, 1948.
- BOLLER, A. Dissertation, Zürich, E.T.H. No. 2047, 1951.
- GÄUMANN, E., NAEF-ROTH, S., and MIESCHER, G. *Phytopath. Z.*, **16**, 257, 1950.
- GÄUMANN, E., STOLL, C., and KERN, H. *Ibid.*, **20**, 245, 1953.
- [8] YABUTA, T., KAMBE, K., and HAYASHI, T. *J. agric. chem. Soc. Japan*, **10**, 1059, 1934.
- GÄUMANN, E., NAEF-ROTH, S., and KOBEL, H. *Phytopath. Z.*, **20**, 1, 1952.
- [9] BAZZIGHIER, G. *Ibid.*, **21**, 105, 1953.
- [10] GÄUMANN, E. and JAAG, O. *Ber. schweiz. bot. Ges.*, **57**, 227, 1947.
- [11] *Idem*. *Experientia*, **2**, 215, 1946.
- [12] DEUEL, H. *Phytopath. Z.*, **21**, 337, 1954.
- GÄUMANN, E. and NAEF-ROTH, S. *Ibid.*, **21**, 349, 1954.
- [13] BROWN, N. A. *J. agric. Res.*, **39**, 747, 1929.
- [14] GÄUMANN, E. *Advanc. Enzymol.*, **11**, 401, 1951.
- [15] *Idem*. 'Pflanzliche Infektionslehre' (2nd ed.), p. 681. Birkhäuser, Basle. 1951.

H. J. H. Fenton (1854-1929): a great teacher

W. H. MILLS

The difficulty now being experienced, in many parts of the world, in recruiting scientific teaching staff, is a reminder of the vital role of the teacher in furthering the progress of science. This sketch of Henry Fenton, published on the centenary of his birth, illustrates how far-reaching can be the influence of an inspiring preceptor. It illustrates, too, that the teaching of science can be far more than the mere distillation of accumulated knowledge; Fenton, like many others, found much inspiration for original research in the work of his students.

There are great chemists and great teachers of chemistry, and the two distinct abilities are seldom found combined in a superlative degree in any one man. When they are not so found, it is normally the great chemist rather than the great teacher who acquires fame, and perhaps it is both inevitable and just that this should be so. Nevertheless, the healthy growth of a science needs inspiring preceptors no less than brilliant pioneers, for inspired teaching will germinate many a dormant seed of talent and give budding genius a propitious atmosphere for blossoming. One outstanding teacher, to whom generations of chemists look back with gratitude and admiration, was Henry John Horstman Fenton, born in London just a hundred years ago.

Fenton was educated at Magdalen College School, Oxford, and afterwards at King's College, London, where Bloxam was then professor of chemistry. At that time, one of the City Companies—merchant guilds of which some were established in London as early as the eleventh to thirteenth centuries—offered an exhibition in physical science tenable for three years by a non-collegiate student at Cambridge. It was won by Fenton, and in accordance with its conditions he entered the university at the beginning of the Lent term, 1875. During his first year he competed successfully for a scholarship at Christ's College and was admitted a scholar of that college in May 1876. He was older than the average undergraduate, and had had considerably greater experience and knowledge of chemistry, so that he was soon appointed assistant demonstrator in the university chemical laboratory. After graduating, Fenton was appointed university demonstrator, and he and his fellow demonstrator, W. J. Sell, were soon carrying out between them the greater part of the teaching in inorganic chemistry in the

university chemical laboratory; in 1904 they were given the title and status of university lecturers.

While Fenton was still an undergraduate, he encountered an observation that was to determine the main course of his subsequent research. Another undergraduate, who was amusing himself by mixing reagents at random, happened to obtain a fine violet colour. Fenton was much interested; having ascertained what reagents had been used, he determined which of them were essentially concerned in the production of the colour and reported his observation in a letter to 'The Chemical News' in 1876: 'I have lately noticed the following reaction which may, as far as I can judge at present, be proposed as a test for tartaric acid. To a very dilute solution of ferrous sulphate or ferrous chloride a small quantity of tartaric acid or a tartrate is added, followed by a few drops of chlorine water or hydric peroxide, when a fine violet colour is obtained. The violet compound appears to be potassic or sodic ferrate.'

Subsequent research showed him that his first diagnosis was incorrect, but it was not until 1894 that he was able to announce that the coloured compound was a ferric derivative of an oxidation product of tartaric acid; this product he successfully isolated as a sparingly soluble crystalline dibasic acid and showed it to be a dihydroxyethylene dicarboxylic acid of the structure $\text{HOOC.C(OH):C(OH).COOH}$. Fenton believed his compound to have the maleinoid configuration and called it dihydroxymaleic acid, though in the light of more recent research it seems almost certain that it must be dihydroxyfumaric acid.

'Fenton's reagent'—hydrogen peroxide in the presence of a trace of ferrous salt—is now known to chemists the world over. With H. Jackson and with H. O. Jones, Fenton himself examined the properties of the oxidizing agent in detail. He

showed that while it smoothly oxidizes glycol to glycollic acid, erythritol to erythrose, and mannitol to mannose, monohydric alcohols are not attacked. It was found also that α -hydroxy acids were rapidly oxidized to the corresponding α -keto-acids, but acids of other types were unaffected. Glycollic acid gave glyoxylic acid, lactic acid gave pyruvic acid, and malic acid gave the previously unknown oxalacetic acid. Fenton's reagent is indeed a specific oxidant for compounds with vicinal hydroxyl groups, dehydrogenating a $=\text{CH}(\text{OH})$ group to $=\text{C}:\text{O}$.

In attempting to change 'dihydroxymaleic acid' into a *trans*-modification he treated it with an ethereal solution of hydrogen bromide but found that this caused only its esterification. He was, however, thus led to try the use of hydrogen bromide and ether as an ethylating agent on other classes of compounds. He found that with certain carbohydrates—fructose in particular—it produced an intense purple colour.

With Miss M. M. Gostling he examined this reaction of fructose in detail and found that the colour arose from the further action of hydrogen bromide on a compound of the molecular formula $\text{C}_6\text{H}_6\text{O}_2\text{Br}$, which could be isolated in considerable quantity, and was subsequently identified as bromomethyl-furfuraldehyde.

Another incident encountered in teaching led him into a different field. In the Journal of the Chemical Society for 1878 he described how a pupil (Street), told to estimate urea, used instead of sodium hypobromite a strongly alkaline solution of sodium hypochlorite and obtained only half of the expected volume of nitrogen.

Fenton followed up this observation and found that the missing half of the nitrogen was left in solution as sodium cyanate. The hypochlorite had thus brought about a reversal of the Wöhler synthesis. Hypochlorites are weaker oxidizing agents than hypobromites; Fenton showed that they do not attack sodium carbamate, which is rapidly decomposed by hypobromites with the evolution of all its nitrogen. It appeared, therefore, that urea in aqueous solution is in equilibrium with a very small proportion of ammonium cyanate,



and that the hypochlorite is unable to act on the urea, but destroys the ammonia liberated from the ammonium ion by the alkali present. The equilibrium is thus disturbed, so that ultimately the whole of the urea is decomposed, with the formation of nitrogen and sodium cyanate.

Fenton was of striking appearance, with black hair, dark complexion, and athletic figure; he lectured with an air of indifference and weariness, but this was plainly a pose, for there was no missing the alertness and vitality that lay beneath.

His unsmiling, sardonic humour was curiously attractive to undergraduate audiences. Should the text-books be found guilty of over-hasty generalization—and they often were—they were denounced with scathing sarcasm. Mordant comments there were in plenty; as on Newlands and his Law of Octaves: 'But he was a chemical manufacturer; so they laughed him to scorn.'

The parts of the subject that interested him most were general and physical chemistry. He was in his early thirties when Arrhenius, Ostwald, and van't Hoff were founding the theory of dilute solutions. He had seen the birth and watched the growth of the new physical chemistry. He had lived through the controversies of that time, and he treated chemistry as a growing science. There was no dogmatism. Subjects were presented wherever possible as debatable questions on which different sides might be taken. The lecturer affected an impartial attitude, and his hearers were encouraged to balance opposing views and draw their own conclusions.

Difficult subjects were approached in the simplest way and treated with a clearness of thought that did much to lessen their difficulty. Interesting questions were suggested for further reflection; unsuspected analogies and relationships were pointed out. His lecture experiments, evolved in the course of years, were well chosen and contrived, and with the aid of his devoted lecture attendant, George Hall, he performed them with great effect.

At the close of each lecture a number of eager young men would come down to the lecture table to discuss with him some of the questions he had raised. He set great store by these informal talks and did all he could to encourage them. Students found him unexpectedly sympathetic with their difficulties, and he would deal very gently with anyone who had asked a thoughtless or ill-considered question.

Fenton retired on reaching the age of seventy and went to live at Hove. He died in a London nursing home on 13th January 1929. The whole of his working life had been spent in the Cambridge University Chemical Laboratory, where his almost fabulous success as a teacher is still vividly remembered.

Histological procedures in cancer research

E. S. HORNING

In Great Britain cancer is the second most common cause of death, and approximately one person in ten is destined to suffer from it; in other parts of the world the situation is comparable. Why the normal multiplication of cells, which even in the adult continues to make up for wear and tear, may suddenly become unrestrained is still unknown, but research has nevertheless led to results of clinical importance in both diagnosis and treatment. Histological research has proved particularly valuable, and some of its results are discussed here.

Cancers consist of masses or growths of newly formed cells which arise in the first place from normal body cells but which, for reasons as yet unknown, continue to divide and multiply without restraint. The new cells cease merely to replace the old ones and begin almost immediately to grow independently of the rest of the body. Their multiplication becomes unlimited, progressive, and uncontrolled; consequently in many cases they invade the surrounding healthy tissues and organs and, if not checked, may rapidly spread throughout the body. The spreading is often accelerated by the breaking away of small groups of cancer cells from the primary growth; these are carried by way of the blood and lymph to quite distant parts of the body. Here they lodge, forming secondary foci or metastases. If vital organs and tissues become obstructed, deranged, or destroyed, death of the whole organism is inevitable.

Unlike many other familiar diseases, cancer is by its very mode of origin almost unlimited in the variety of its manifestation. Some growths or tumours, for instance, remain strictly localized at their point of origin. Some indeed grow so slowly, without spreading, that the tumour may be little more than an inconvenience or an unsightly blemish. Such tumours are classified as benign, in contrast to the malignant variety mentioned above. The clinician must determine not only whether tumour cells exist in the body, but whether they are growing as a benign or as a malignant tumour, and what variety of normal cell originally became cancerous. Thus it is usually a matter for grave concern if the pigmented cells of the body or the blood cells are involved, whereas if it is simply a question of fat cells proliferating the outlook may be much more hopeful.

MICROSCOPY IN DIAGNOSIS AND RESEARCH

Much of the knowledge we have obtained of differences in behaviour between normal and

malignant cells, and in particular of the mode of growth and infiltration of cancer throughout the body, has been obtained by the use of the microscope. The actions of radiations, drugs, chemicals, or hormones upon a malignant growth, and the ultimate fate of the cancer cell after any of these forms of treatment, can be revealed by the histological or cytological approach. A thin slice or section of the cancerous tissue is generally needed; this can be stained to emphasize structural characteristics. In some cases, where minute groups of cancer cells can be isolated, it is sufficient to smear them on a glass slide before staining. There is a vast literature dealing with the purely descriptive aspects of the histological and cytological structure associated with different forms of cancer, including the early stages when the neoplastic changes are first detectable. While the techniques of sectioning and microscopy, when routine diagnosis of cancerous conditions is required, are much the same as those used in conventional histology, some techniques have been specially adapted for work in this field.

TRANSPLANTATION OF CANCER IN ANIMALS

In order to study the structure and behaviour of the cancer cell it is necessary for the cellular pathologist to have available living malignant cells. Most cancer research laboratories keep inbred strains of mice in which a high percentage develop spontaneous tumours, as well as rodents of indeterminate ancestry which can bear grafted or transplantable cancers. The cytologist depends mainly on the latter material.

At the close of the last century it was discovered that certain spontaneous animal tumours could be transferred by grafting small pieces of the tumour under the skin of animals of the same species. In this way cancer can be propagated from animal to animal for an unlimited number of generations. Some animal neoplasms, such as the Walker carcinoma, have been kept going continuously for

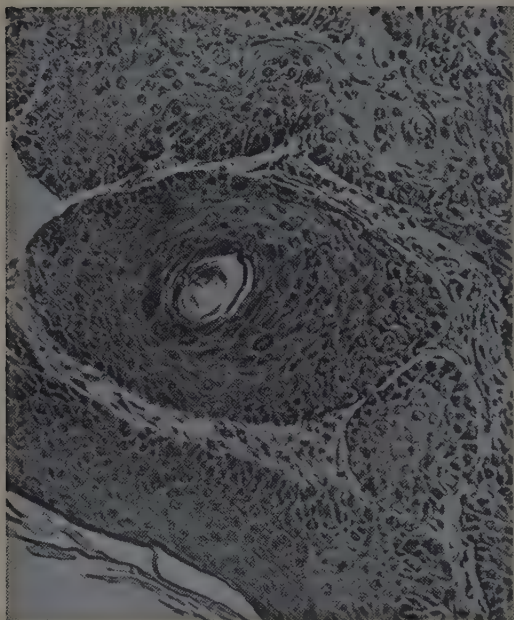


FIGURE 1 - Photomicrograph, by direct illumination, of a control section of a mouse tar-tumour, showing tarred skin, stroma, and underlying tumour cells. The preparation was stained with Ehrlich's haematoxylin, after fixation in alcohol-formalin. ($\times 150$)



FIGURE 2 - Incineration section, similar to that seen in figure 1, photographed in dark field illumination. SG = tarred skin; TC = underlying tumour cells. ($\times 150$)

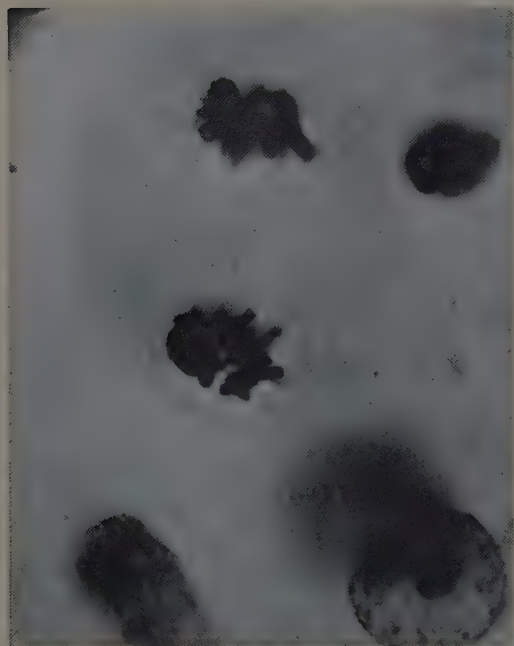


FIGURE 3 - Normal division (anaphase) in a transplanted Walker rat tumour. ($\times 2500$)

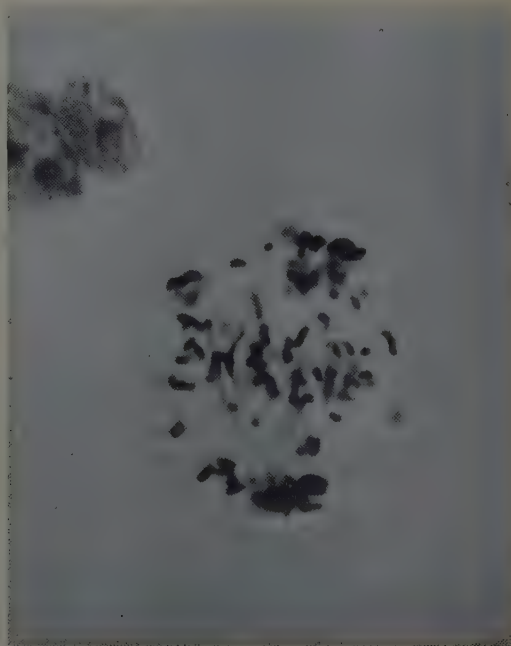


FIGURE 4 - Illustration of the effects of HN2, 24 hours after injection, on the chromosomes of a Walker tumour. ($\times 2500$)



FIGURE 5—Multifocal malignant nodules in both kidneys of a male hamster following prolonged treatment with stilboestrol. (Natural size.)



FIGURE 6—Kidneys of male hamster without tumours; compare with figure 5. (Natural size.)

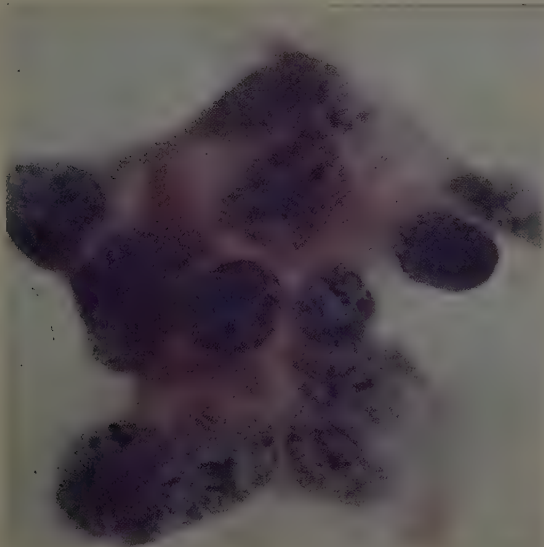


FIGURE 7—Isolated group of human carcinoma cells seen in urine deposit of man suffering from advanced cancer of the bladder. ($\times 1000$)

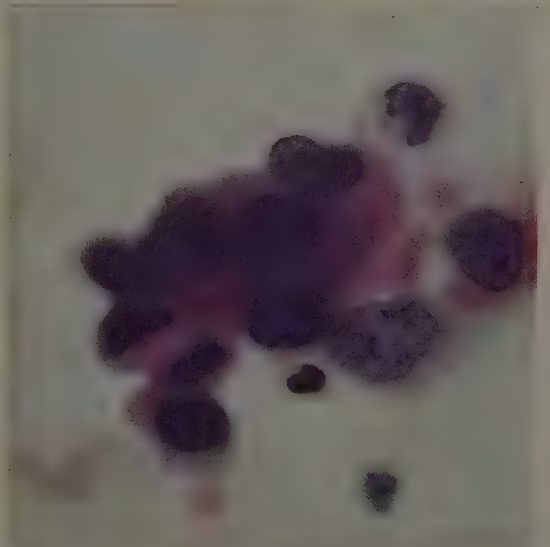


FIGURE 8—The same material as for figure 7. One malignant cell is seen in division. Note abnormal chromosome. ($\times 1000$)

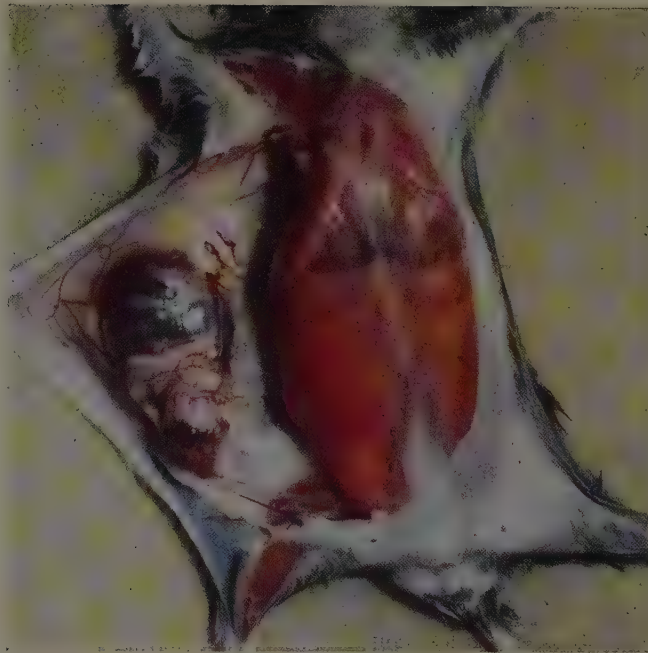


FIGURE 9 - *Transplantable renal tumour growing subcutaneously in a male hamster which had previously been treated with stilboestrol. ($\times \frac{1}{2}$)*

nearly half a century. Tumours in animals which have been induced by a chemical carcinogen are also transplantable in some cases. Figure 9 shows a transplantable renal tumour growing under the skin of a host male hamster. This particular kidney tumour was induced in a male hamster following treatment with diethyl-stilboestrol, a synthetic oestrogen having an action similar to that of the female sex hormone. These tumours arise only in oestrogen-treated males and never in females (see figures 5 and 6); renal tumours can rarely be grafted and will in fact respond to grafting only if the new host hamster has first been treated with oestrogen. With material of this kind, and with the great variety of spontaneously occurring human and animal cancers, the histologist and cytologist can work.

ABNORMALITIES OF THE CANCER CELL

The two most common cytoplasmic constituents of both normal and malignant cells are the mitochondria and the Golgi bodies. In some cancer cells these inclusions undergo morphological changes which seem to be dependent upon the degree of cellular differentiation and the func-

tional state of the cell. Numerous investigations have shown, however, that similar changes can be produced experimentally in normal healthy cells, and that there are really no microscopical features of the cytoplasm that can be relied upon to distinguish a cancer cell from a normal one. Greater attention has been focused, therefore, on the nucleus. It has been known since last century that the successive stages of the scanty cell divisions seen in benign tumours usually appear normal, but that in rapidly growing malignant cancers the mitotic figures which appear in cells during division are more frequent, and many types of nuclear abnormalities appear. The proportion of cancer cells that are dividing at any given time is, of course, an indication of the rate of growth of a tumour. According to Willis [1], rapidly growing tumours may show mitotic figures in 5 per cent or more of their cells, and the proportion never exceeds 10 per cent. Stroebe [2], Pianese [3], von Hansemann [4], and others described structural abnormalities such as hyperchromatism (increased staining of the nuclear contents), giant multiple nuclei, enlarged nucleoli, and abnormal cell divisions. Great hopes were raised that these nuclear

abnormalities might be an essential feature of malignancy, until it was found that abnormal mitosis can be induced in normal cells by chemical agents. They can also be seen in ordinary tissues regenerating after injury (Cowdry [5]). This problem has been reviewed by Levine [6], Ludford [7], and Koller [8].

Many cancer cells possess a tetraploid or polyploid number of abnormal chromosomes. Koller, studying material obtained from transplantable rodent tumours as well as human cancers, has discussed the factors causing failure of cell division, and other mechanisms which induce chromosome abnormalities. Most frequent is 'stickiness' of the chromosomes, which are irregular or polyploid in number and the division of which is invariably accompanied by a partial or complete suppression of the mitotic spindle. According to Koller, these abnormalities are due to lack of adequate food supply, as well as to the accumulation of toxic breakdown products.

Although many therapeutic agencies can induce nuclear abnormalities in the normal cell, the cancer cell is so often abnormal in nuclear structure that much more reliance can be placed upon structural changes in the nucleus than upon almost any other supposed criterion of malignancy.

DIAGNOSIS BY THE SMEAR TECHNIQUE

The routine histological procedure for cutting sections is not only rather slow for the purpose of cancer diagnosis, but is apt to distort the cells in such a way that nuclear abnormalities are less easily detected. The smear technique was used by Belling [9] for the comparative study of animal and plant chromosomes, and it became very well known when Papanicolaou showed that smears of cells swabbed from the lining of the vagina of various mammals could be used in assessing the stages of the sexual cycle. Koller [10, 11] was one of the first to employ the smear technique in the study of experimental cancer in animals (see figure 7). Small fragments of cancer tissue or drops of body fluids containing cancer cells, for example from the peritoneal cavity, are placed on a slide. After the tissue has been carefully teased to separate the cells, a few drops of a combined fixing and staining solution are added. It takes only 5-10 minutes to complete the preparation. The advantage of such a simple technique in cancer diagnosis is obvious, provided, of course, that the small fragments of tissue can be taken at biopsy or isolated from such fluids as urine.

Equally important is the use of the smear tech-

nique in certain kinds of chemotherapeutic research. It helps the cytologist in observing a sequence of changes if repeated samples are taken during the course of a prolonged experiment, and gives valuable information in determining the correct dosage of a particular therapeutic agent. Within limits, the degree of malignancy can be assessed at frequent intervals, and this is often quite important in tumour material showing variations in growth behaviour. Koller [11] has also applied the technique to a comparative study of the responses of normal and malignant cells to various carcinogenic agents. These studies show that abnormal chromosome behaviour is one of the most important signs by which cell reaction to chemical agents can be measured (figures 3 and 4).

Although the smear technique appears very simple, it requires considerable experience to obtain preparations free from cellular distortion; no amount of skill will enable even an experienced cytologist to diagnose cancer cells unless the material has been carefully collected. Special training in nuclear cytology is required to arrive at a reliable diagnosis. The smear technique cannot be used for a rapid diagnosis of every type of cancer, and in human cases confirmation of the initial findings is usually obtained from biopsy material examined in sections, or, in the case of prostatic cancer, by certain chemical tests.

Cancers of the urinary bladder, the lung, the breast, and, to a lesser extent, the female genital tract provide the material most successful for cyto-diagnosis. Figure 7 shows a smear of cells isolated from the urine of a man suffering from advanced cancer of the bladder. Isolated groups of cancer cells, readily recognizable by their cytological character, include a cancer cell in division at the time of fixation and showing an abnormal chromosome (figure 8). Routine biopsies of the bladder are difficult to obtain, and this example forcibly illustrates the great advantage of this method.

Albers, McDonald, and Thompson [12] have applied the smear technique in the United States for detecting cancer of the prostate gland, which also is rather inaccessible for routine biopsy. In several instances they have detected malignant changes in the prostate by the smear technique even before the disease was clinically evident. This is quite important, because in some individuals the prostate gland undergoes benign hypertrophy rather than a truly cancerous change. During the past twenty years or so much work has been done on smears of human sputum from patients suffering from bronchial carcinoma. Owing to the

alleged correlation between cigarette smoking and lung cancer we may expect new modifications of staining technique as applied to smear preparations. Recently an interesting annotation [13] was published on the diagnosis of bronchial cancer; in this the value of the smear technique was particularly stressed, as this form of cancer may not become apparent in X-ray films until far advanced. It is stressed that considerable experience is needed to distinguish cancer cells from others found in the bronchial exudate. The results of Jennings and Shaw [14] are quoted as confirming the value of smear examination, since 82 per cent of patients with bronchial tumours gave a positive smear diagnosis, whereas only 45 per cent could be identified as having the disease when other methods of diagnosis were used. In almost two-thirds of cases in which cancer was located at the periphery of the lungs, beyond the range of bronchoscopic vision, a positive sputum test was recorded.

Similarly in breast cancer the smear technique has great advantages, but there is a complex cellular exudate from the mammary gland, even in the absence of cancer, which makes it unwise to base a diagnosis of malignancy on a single preparation. Osborn has discussed some pitfalls of cytodagnosis and, for those who wish to learn more, his book [15] is strongly recommended, as well as another interesting monograph [16].

MICRO-INCINERATION OF CELLS

This technique, in which thin sections of suitably fixed tissues are incinerated at high temperatures, leaving behind the inorganic components of the cells, is not a histological technique that can help in the diagnosis of cancer, but it can be applied to a limited range of research problems. After the sections have been incinerated on quartz or glass

slides, they are first examined by transmitted light to ensure that carbon residues have been removed. In dark field illumination the ash can be seen as a more or less opaque white deposit preserving with remarkable clarity the contours and internal structure of the individual cells. Only three substances—compounds of calcium, iron, and silicon—can be identified with any certainty by their colour in dark field illumination or, in the case of silica, by its birefringence in polarized light. Until more precise methods are devised for the identification of the ash components, the value of the method lies principally in the determination of variations in total non-volatile ash content and in its distribution. Variations are considerable in tumours and appear to be correlated with varying degrees of cellular differentiation. Scott and Horning [17] have recorded mineral content changes in neoplasms associated with different degrees of malignancy (figures 1 and 2).

The effect of radium treatment upon the mineral organization of transplantable cancer cells in rodents has been studied by Horning [18], who found that a marked increase of calcium occurred in tumour cells as early as 6–8 hours after irradiation, reaching a maximum on the sixth day. The initial increases seemed to indicate that the permeability of the cell membranes to calcium ions had been increased by the radium radiations. This technique has been used to examine the mineral organization in many other pathological conditions (Horning [19, 20]).

ACKNOWLEDGMENTS

I am greatly indebted to Professor P. C. Koller for photomicrographs 3 and 4, and to Mr P. M. Wallace, F.R.C.S., for supplying me with material used in figures 7 and 8. All the photomicrographs were taken by Mr F. Speed, F.R.P.S., F.I.B.P.

REFERENCES

- [1] WILLIS, R. A. 'Pathology of Tumours.' Butterworth and Co. (Publishers) Ltd., London. 1948.
- [2] STROEBE, H. *Beitr. path. Anat.*, 7, 339, 1890.
- [3] PIANESE, G. *Ibid.*, Suppl. 1, 1896.
- [4] HANSEMAN, D. VON. *Virchows Arch.*, 119, 299, 1896.
- [5] COWDRY, E. V. *Arch. Path. (Lab. Med.)*, 30, 1245, 1940.
- [6] LEVINE, M. *Amer. J. Cancer*, 15, 144, 1931.
- [7] LUDFORD, R. J. *Imp. Cancer Res. Fund xi Sci. Rep.*, 147, 1934.
- [8] KOLLER, P. C. *Brit. J. Cancer*, 1, 38, 1947.
- [9] BELLING, J. *Biol. Bull., Wood's Hole*, 50, 51, 1926.
- [10] KOLLER, P. C. *Nature, Lond.*, 149, 193, 1942.
- [11] *Idem. Lab. Practice*, 2, 473, 1953.
- [12] ALBERS, D. D., McDONALD, J. R., and THOMPSON, G. T. *J. Amer. med. Ass.*, 139, 299, 1949.
- [13] *Lancet*, 266, 611, 1954.
- [14] JENNINGS, R. C. and SHAW, K. M. *Thorax*, 8, 288, 1953.
- [15] OSBORN, G. R. 'Applied Cytology.' Butterworth and Co. (Publishers) Ltd., London. 1953.
- [16] 'The Cytologic Diagnosis of Cancer' by the Staff of the Vincent Memorial Hospital Laboratory, Boston, Mass. W. B. Saunders & Co. Ltd., London. 1950.
- [17] SCOTT, G. H. and HORNING, E. S. *Amer. J. Path.*, 8, 329, 1932.
- [18] HORNING, E. S. *Imp. Cancer Res. Fund xi Sci. Rep.*, 55, 1934.
- [19] *Idem. Ibid.*, 67, 1934.
- [20] *Idem. 'Cytology and Cell Physiology' (Ed. G. H. Bourne). Clarendon Press, Oxford. 1951. Pp. 287–321.*

The origin of lizards

E. KUHN-SCHNYDER

The problem of the evolution of lizards is of considerable biological interest, since they represent an important vertebrate sub-order. While much information has been obtained from fossil remains, there has been a dearth of direct palaeontological evidence for the period separating the lizard-like *Prolacerta* of the Lower Triassic from the true lizards of the Upper Jurassic. New light has been thrown on this critical period by excavations at Monte San Giorgio (Switzerland), with which the writer of this article has long been associated.

Up to some 300 million years ago, the only vertebrates were fishes, populating lakes, rivers, and seas. One group then succeeded in making a decisively important step: the emergence from water on to land. To meet the new needs a form of spinal column was evolved that was at once mobile and capable of bearing weight. The need was fulfilled in the most varied ways among amphibians, and one of the designs was used for the reptiles, which, however, became fully emancipated from aquatic life. There were various changes in the construction of the skull. To allow freedom of movement of the head, a typical neck was developed. One group of reptiles acquired the capacity to chew food, a normal prerequisite for warm-bloodedness, and this developed into the mammals, among which the development of dentition was of exceptional importance (figure 1).

Those parts of the skeleton that were undergoing profound modification during a given period of evolutionary change are particularly suited for characterizing the various forms typical of that stage of organization. Thus, the spinal column is significant for amphibian systematics; the structure of the skull for reptiles; the study of dentition in mammalian systematics. In discussing the origin of lizards (Squamata, sub-order Lacertilia),

decisive results are therefore to be expected from consideration of the structure of the skull.

The oldest reptiles (Cotylosauria) show, like their amphibian ancestors (Labyrinthodontia), a closed cranial vault. They are therefore known as Anapsida, reptiles without arches or vaults. The tortoises and turtles show a survival of this condition, with some modifications. Descendants of the early anapsid reptiles had a stronger jaw-musculature, and for the attachment of these muscles there developed cavities in the temporal areas of the skull. These cavities were limited by temporal vaults (figure 2). H. F. Osborn [16] separated the reptiles into two sub-classes, Synapsida and Diapsida, according to whether they had one or two temporal arches respectively. Broadly speaking, Osborn's concept was correct: as knowledge of types of fossil reptiles grew, two successful lines of development became increasingly obvious. The Archosaurs, whose origin can now be traced back to the Triassic, were the dominating vertebrates of the Jurassic and the Cretaceous (Dinosaurs); they culminated in the birds of today. All the representatives of these classes, to which the crocodiles also belong, are either diapsids or descended from diapsids. The other, synapsid, line led from the Pelycosaur of the Permian,

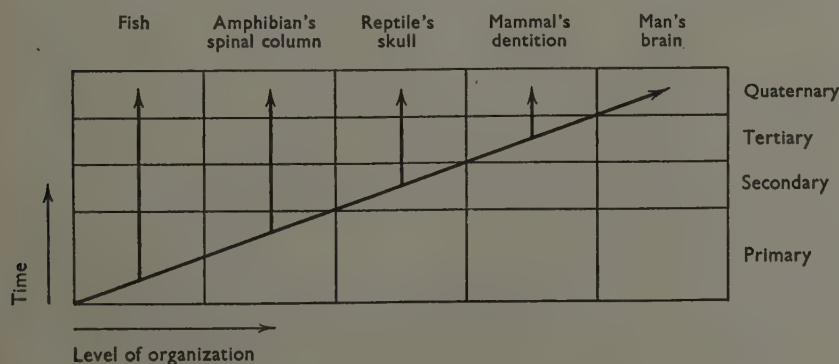


FIGURE 1 - Stages in organization of vertebrates.

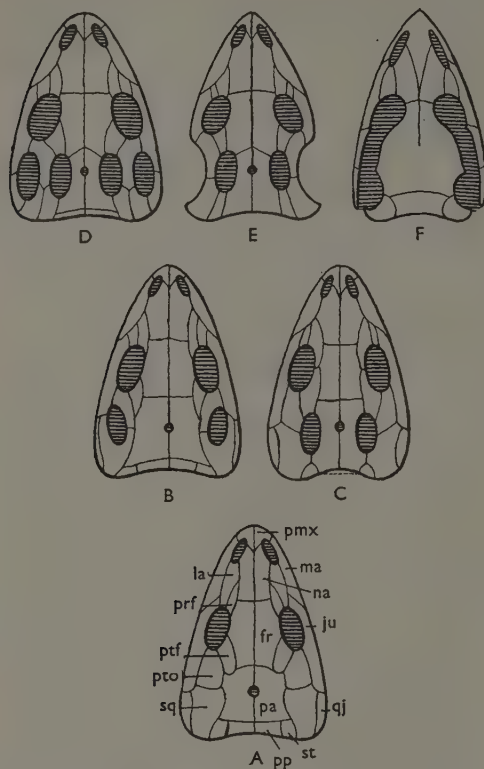


FIGURE 2—Diagrammatic representation of cranial relationships in reptiles and birds. A, anapsid; B, synapsid; C, parapsid; D, diapsid; E, Squamata (lizards); F, Birds. Key: fr = frontal bone; ju = jugal; la = lacrimal; ma = maxillary; na = nasal; pa = parietal; pmx = premaxillary; pp = postparietal; prf = prefrontal; ptf = postfrontal; pto = postorbital; qj = quadratojugal; sq = squamosal; st = supratemporal. (Based on drawings by R. Broom.)

through the Therapsida of the Permian and Triassic, to the mammals. In the shadow of these progressive groups of reptiles, however, other branches survived: ancestors of tortoises, of lizards, and of the Rhynchocephalia (*Sphenodon* and others). To these must be added other types, which chose the sea to live in but which became extinct during the Mesozoic (figure 4). The splitting up of these side branches began towards the end of the Palaeozoic and was completed during the Triassic.

Palaeontology alone can show the exact course of the history of the animal world; if fossil evidence is lacking, one can only speculate on the course of evolution. Until quite recently, palaeontologists had not succeeded in discovering fossil lizards more primitive than the most primitive types still living; decisions on the place of lizards in syste-

matics depended therefore on interpretation of the results of comparative anatomy and embryology. M. Fürbringer [11], who had made a detailed anatomical study of the construction of the chest and shoulder region in living reptiles, came to the conclusion that lizards and Rhynchocephalia were closely related; he put them in the subclass Toco-sauria, in which he also included the marine ichthyosaurs. In 1937, Sir Gavin de Beer [2] came to the same conclusion on the basis of embryological investigations. Among palaeontologists opinion was divided. Some distinguished workers (S. W. Williston [25, 26], D. M. S. Watson) supported a sharp systematic separation between lizards and Rhynchocephalia.

There are, in fact, considerable differences between lizards and Rhynchocephalia (figure 3). The skull of the latter shows two temporal openings, and hence an upper and a lower temporal arch. The typical lizard cranium, on the other hand, has only one temporal opening. Moreover, the behaviour of the quadrate, the bone of the skull which provides the articulation with the lower jaw, is distinctive. In most lizards the quadrate is mobile, a condition known as streptostyly. The quadrate in the Rhynchocephalia is joined solidly to the skull, a condition known as monimostyly. The relationships of the lizard skull can be interpreted in two ways. According to one, they originally possessed two temporal openings, like the Rhynchocephalia; if the lower temporal arch was then reduced, we should have the relationship existing today. According to the other,

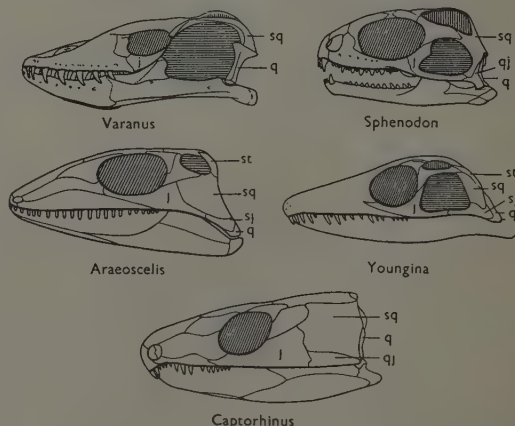


FIGURE 3—Primitive and developed skull types in reptiles. Key: j = jugal; q = quadrate; qj, sj = quadratojugal; sq = squamosal; st = supratemporal. (Based on drawings by R. Broom, W. K. Greenwood, and A. S. Romer.)

the lizard cranium originally possessed only one temporal opening; if this is proved true, there can be no question of a close relationship between lizards and Rhynchocephalia.

A fossil skull found in Texas in 1912, and another found in South Africa a year later, were each claimed as a demonstration of the correctness of one or other of the two hypotheses. S. W. Williston [25, 26] believed he had discovered the ancestral type of the lizard in *Araucoscelis*, from the Permian-Carboniferous in Texas. *Araucoscelis* has only one temporal opening and an immobile quadrate, and Williston was convinced that the link with the lizard skull had been made by emargination of the temporal bone and subsequent streptostyly.

Not all palaeontologists, however, were convinced by *Araucoscelis*. R. Broom, in particular, did not agree, and in the same year he described [4] the skull of a fossil reptile, *Youngina*, from the *Cistecephalus*-zone of the Beaufort Beds (Upper Permian) in South Africa, which showed two temporal openings. If the lower temporal arch is reduced, the quadrate becomes capable of movement. *Youngina* also shows a bone, the supra-temporal (tabulare Broom), on the posterior, inner edge of the upper temporal opening, which persists in the lizards living today. No supra-temporal is present in the Rhynchocephalia, but their ancestors show it. Only a few further finds of *Youngina* and related types have been made in South Africa [9], that treasure-house of fossil reptiles, and Broom [5, 6] classed them together under the name of *Eosuchia* (figure 5). No trace of a true lizard was found, and resignedly it was supposed that they had developed only much later, in Upper Jurassic or Cretaceous times.

It was, however, again South Africa that, in 1935, drew the attention of palaeontologists. In that year F. R. Parrington [17] described a small lizard-like reptile—*Prolacerta*—from the Lystrosaurus Beds (Lower Triassic). In the same year, C. L. Camp [10] discovered a further specimen, which he investigated and described in detail. *Prolacerta* occupies a place midway between *Youngina* and the lizards (figure 5). The lower temporal arch of *Prolacerta* is not closed and the quadrate is streptostylic. The derivation of lizards from types having two temporal openings was thus made certain: lizards and Rhynchocephalia are therefore closely related.

At this point mention must be made of a further peculiarity of the reptilian skull. According to J. Versluys, the lizard cranium is kinetic [22]. It consists of two sections, having no solid connec-

tion with one another: an occipital segment can be moved against a maxillary segment. When the mouth is opened, the occipital segment remains fixed to the vertebral column; special muscles move the maxillary against the occipital segment. The cranium of the Rhynchocephalia lacks this mobility. Which behaviour is the more primitive?

Palaeontology can show that a kinetic skull is found in the ancestral forms of the reptiles; *Youngina* and *Prolacerta* both have such skulls. In this respect the lizard skull has remained more primitive than that of the Rhynchocephalia. The akinetic skull of Rhynchocephalia represents a modification: it is specialized for a particular manner of feeding and the dentition is highly specialized. Besides worms and insects, the tuatara (*Sphenodon*) eats snails and mussels. That the skull of the Rhynchocephalia must be descended from a type having a kinetic skull accords with embryological research. The articulated connection between the two cranial segments, the basipterygoid joint, is well developed in the embryo; the associated muscles are attached, but later retrogress.

The connections between Lepidosauria (lizards, Rhynchocephalia, and related reptiles) and Archosaurs need a little more explanation. Both groups have a primitive skull with two temporal openings,

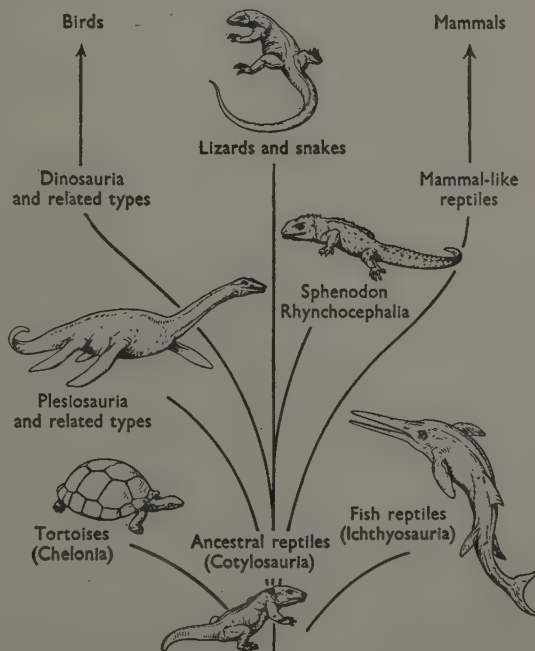


FIGURE 4—Main and side branches of reptiles. (Based on drawing by A. S. Romer.)

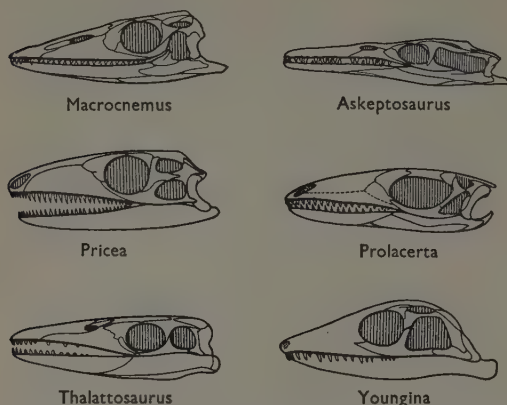


FIGURE 5—*Eosuchia* and early *Squamata*. According to R. Broom; R. Broom and J. T. Robinson; C. L. Camp; E. Kuhn-Schnyder; and A. S. Romer.

but their present-day representatives show fundamental anatomical differences. Thus crocodiles (Archosaurs) have a simple penis and an elongated cloacal opening, while lizards and snakes have a transverse cloacal opening and a double penis. Experience teaches us caution in using the nature of the temporal opening as a systematic criterion, for it depends originally on the formation of the jaw musculature and on the dentition; that is to say, on the kind of feeding. In certain circumstances a parallel development might have occurred in both Archosaurs and Lepidosaurs.

Prolacerta dates from the Lower Triassic; true lizards do not appear until the Upper Jurassic [3]. To discover if our proposed type sequence were correct it needed confirmation by further finds from within this enormous time-span of about 50 million years. Excavations in the southern Alps, initiated in 1924 by B. Peyer, the present director of the zoological museum of Zürich University, have shed new light on this subject. The author was fortunate in that, as a young student, he was able to take part as early as 1925 in these excavations, which were made possible by donations from the 'Georges und Antoine Claraz-Schenkung.'

At Monte San Giorgio, south of Lugano, there are deposits from Tethys, the great Mediterranean sea of former ages. Bituminous layers, which alternate with beds of dolomite, are especially rich in reptiles and fishes belonging to the upper section of the anisian stage of the Triassic (Middle Triassic). Bodies of marine reptiles (Ichthyosaurs) were washed up on this shore, and Saurians which led an aquatic life are dominant in these beds. There are numerous examples of the *Sauropterygia*,

which used their limbs for swimming. Associated with them are the *Placodontia*, whose jaws are provided with large, blunt teeth which they used for crushing their hard-shelled prey. The Monte San Giorgio deposits are at present the richest source of marine reptiles of the Middle Triassic. Marine vertebrate fauna of equal antiquity are known only from Spitsbergen and Nevada. Moreover, the shore-deposits of Monte San Giorgio also shelter the remains of reptiles that led an amphibious life or did not normally inhabit the sea. Among them is a type-series of reptiles, the position of which in the natural system has up till now been very uncertain: *Tanystropheus*, *Macrocnemus*, and *Askeptosaurus*.

It is a striking fact that the majority of our finds consist of more or less complete skeletons: the embedding of the bodies must have occurred quickly. The skeletons, especially in the bituminous layers, are invariably compressed and deformed without breakage; the extent of this strong deformation indicates that the watery ooze settled down to just over a tenth of its original bulk. Reconstruction of the parts is usually necessary to give a proper idea of the structure of the deformed skulls and shoulder and pelvic girdles. X-ray photographs (figures 6 and 7) have proved a valuable aid to the preparation of specimens and their scientific interpretation.

We were not the first to excavate systematically the Triassic beds of the southern Alps. In 1863 and 1878 the Milanese worked in bituminous shales near Besano (Varese, Italy). F. Bassani [1] gave a brief report on these researches in 1886, but the great monograph which was heralded was never published. Only a few experts knew what interesting vertebrate remains were hidden in the Milan Museum, and only one foreign palaeontologist, the Hungarian Baron Franz von Nopcsa, visited Milan frequently. He studied the puzzling 'flying reptile,' *Tribelesodon* [13], and made a reconstruction of it, and he also took an interest in the remarkable *Macrocnemus* [15]. He discovered, too, a reptile overlooked by Italian palaeontologists, *Askeptosaurus italicus* [14]. We succeeded in excavating complete remains of these three.

Nopcsa was a research worker with original ideas, but it remains to be seen which of the ideas he put forward are sound. In the light of recent research, his conclusions on the systematic position of *Askeptosaurus*, *Macrocnemus*, and *Tanystropheus* may be assessed as follows.

Askeptosaurus italicus Nopcsa. In 1925 Nopcsa [14] had only a small hip-bone (ilium) and the

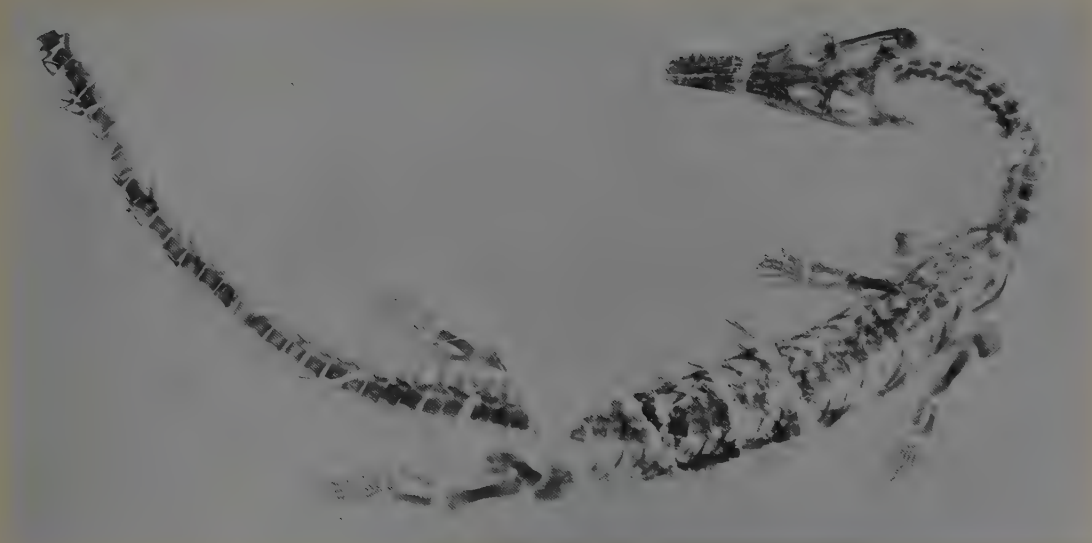


FIGURE 6 - *Askeptosaurus italicus* Nopcsa; from an X-ray photograph prepared at the X-ray Institute of the Cantonal Hospital, Zürich (Director, Professor H. R. Schinz). (After E. Kuhn[-Schnyder], 1952.) ($\times \frac{1}{7}$)

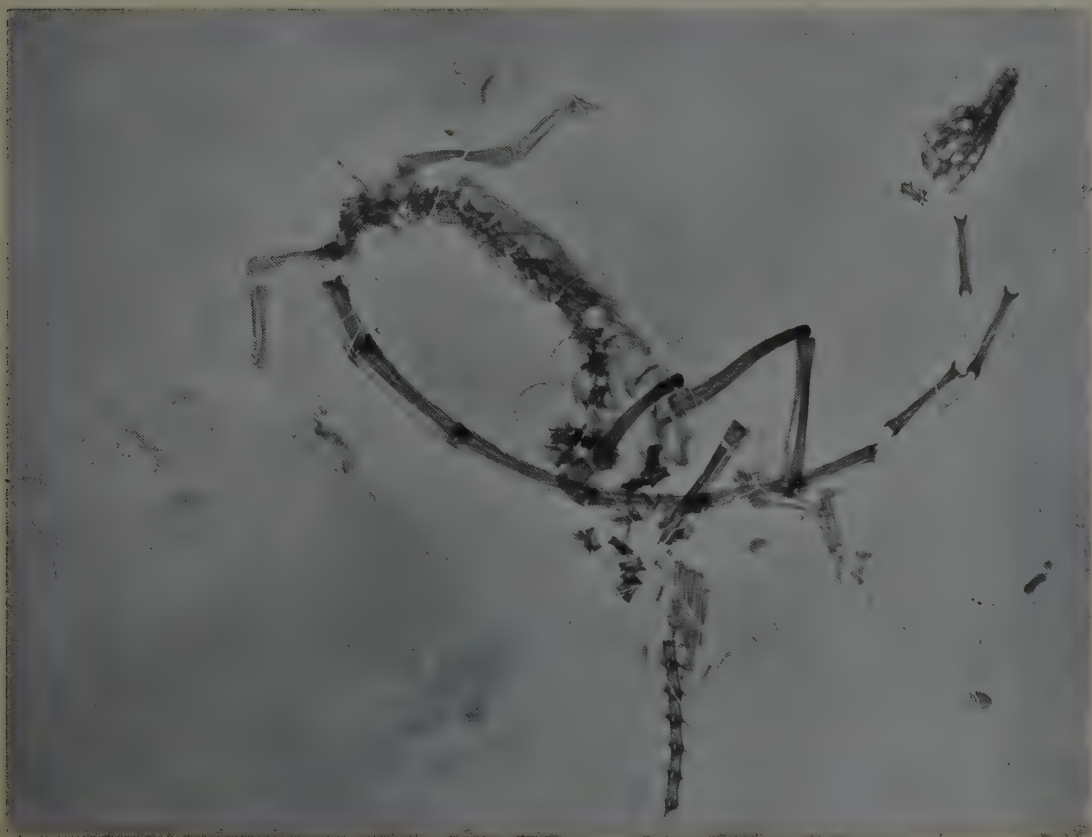


FIGURE 7 - *Tanystropheus longobardicus* (Bass.). From an X-ray photograph prepared at the X-ray Institute of the Cantonal Hospital, Zürich (Director, Professor H. R. Schinz). (From B. Peyer, 1931.) ($\times \frac{3}{4}$)

microscopical structure of the ribs on which to base his identification of this new genus and species (figure 8). He came to the conclusion that these were the remains of a type of reptile previously unknown, probably belonging to the type-series of older lizards, about which so little was known up to that time. Investigation of the new material by E. Kuhn[-Schnyder] [12] showed that *Askeptosaurus* has two temporal openings, the lower of which is not closed (figures 5, 6). A supratemporal is present. The quadrate is mobile, the skull kinetic. Despite the scarcity of material Nopcsa recognised the systematic position of this fossil with unusual perspicacity; *Askeptosaurus* is a specialized representative of early lizards. Besides some characteristics typical of life on land, its skeleton shows a number of peculiarities which can be explained only by assuming an amphibious mode of life.

It is related to the marine *Thalattosaurus* from the Upper Triassic of California.

Macrocnemus bassanii Nopcsa. The badly preserved remains of one originally complete specimen were all the material available to Nopcsa [15] in 1930. In his short note he has, therefore, given only a diagram (figure 10) to show the remarkable proportions of the animal. Nopcsa placed *Macrocnemus* close to the Permian genus *Araeoscelis*; in 1937 the new material was described by B. Peyer [19] in a comprehensive monograph. Detailed comparison with *Tanystropheus* shows certain relationships. Here, too, Nopcsa's opinion seemed to be further confirmed. Peyer [20] first placed *Macrocnemus* with *Tanystropheus*, and *Protorosaurus* and *Araeoscelis* among the Protorosaurs, and he further emphasized a relationship with the Squamata and the Rhynchocephalia. As it was not possible to explain the cranial structure of *Macrocnemus* with sufficient clarity, the writer has recently attempted a plastic reconstruction with the aid of further fresh material now available. There is no doubt about the results (figure 9). *Macrocnemus* has two temporal openings; the lower temporal arch is incomplete; the quadrate is

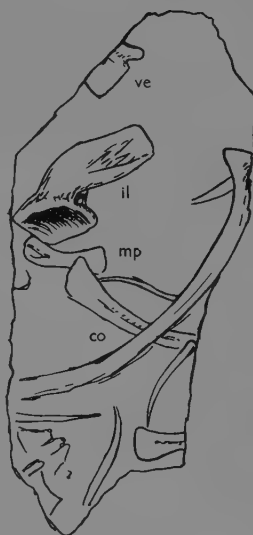


FIGURE 8—Type specimen of *Askeptosaurus italicus* Nopcsa. Key: il = ilium. (After F. v. Nopcsa, 1925.) (Approx. natural size.)

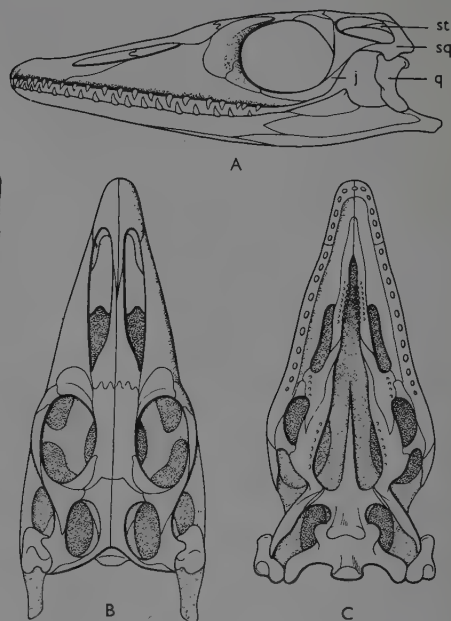


FIGURE 9—Reconstruction of skull of *Macrocnemus bassanii* Nopcsa. A, Side view; B, seen from above; C, seen from below. Key: j = jugal; q = quadrate; sq = squamosal; st = supratemporal. (E. Kuhn[-Schnyder].)

streptostylic, the skull kinetic; a supratemporal is present. *Macrocnemus* must be placed in the type-series of the older lizards. There is no close relationship to *Araeoscelis*. The skull structure of *Protorosaurus* remains as yet unknown.

Tanystropheus longobardicus (Bassani). A find from Besano was at first described by F. Bassani [1] in 1886 as *Tribelesodon longobardicus*, and Nopcsa [13] made a fresh investigation in 1923; both authors referred to it as the earliest flying reptile (figure 11). A few vertebrae and the remains of a lower jaw came to light as a result of a fall of rock in one of the galleries of the Cava Tre Fontane on Monte San Giorgio in the spring of 1927, and it was possible to identify the vertebrae as belonging to the mysterious *Tanystropheus*. Such vertebrae, which had been known for more than a century from the *Muschelkalk* of Bayreuth, had been identified as tail-vertebrae of dinosaurs. In the summer of 1929 the Museum's excavations yielded the fossil shown in figure 7; the vertebrae of *Tanystropheus* are in fact neck-vertebrae. The enormous length of the neck of this reptile is attained, like that of the giraffe, by elongation of the separate vertebrae. Further examination of the Milan fragment of



FIGURE 10 – *Macrocnemus bassanii* Nopcsa. The dinosaur-like attitude of the animal is not correct. (After F. v. Nopcsa, 1930.) ($\times \frac{1}{2}$)



FIGURE 11 – Incorrect reconstruction of *Tribesodon* (*Tanystropheus*) as a parachute-flyer. (From F. v. Nopcsa, 1923.) ($\times \frac{1}{2}$)

Tribesodon has shown that the supposed flying reptile is in fact *Tanystropheus*. The series of elongated neck-vertebrae was interpreted by Bassani and Nopcsa as being elements of the wing finger. A monograph on the new finds of *Tanystropheus* was published in 1931 by B. Peyer [18], who was originally inclined to identify *Tanystropheus* as one of the Sauropterygia, types which have one temporal opening. The systematic position was further clarified by the evidence of its relationship with *Macrocnemus* [19]. A reconstruction of the lower side of the cranium, which the writer made a few years ago, did show that in fact the skull of *Tanystropheus* is kinetic. The quadrate is streptostylic, and the lower of the two temporal openings is not closed. *Tanystropheus* was a highly specialized lizard living, in the Middle

Triassic, on the coasts of both Tethys and the Germanic inland sea. It could attain a total length of about 6 metres, though the functional significance of the elongated neck remains a riddle.

Askeptosaurus, *Macrocnemus*, and *Tanystropheus* show that the lizards date back to the Middle Triassic, and the occurrence of these specialized types is evidence for the view that the lizards were passing through a first period of development at even that early date. The drift to the sea was already going on; *Askeptosaurus* and *Thalattosaurus* confirm this. During the Cretaceous, a branch of the lizards, the mighty Mosasaurs, went back again to the sea.

REFERENCES

- [1] BASSANI, F. *Atti Soc. ital. Sci. nat.*, **29**, 15, 1886.
- [2] DE BEER, G. R. 'The Development of the Vertebrate Skull.' Clarendon Press, Oxford, 1937.
- [3] BROILI, F. *S. B. bayer. Akad. Wiss.*, 97, 1938.
- [4] BROOM, R. *Proc. zool. Soc. Lond.*, 1072, 1914.
- [5] *Idem.* *Bull. Amer. Mus. nat. Hist.*, **51**, ii, 39, 1924.
- [6] *Idem.* *Ibid.*, **51**, iii, 67, 1924.
- [7] *Idem.* *Proc. zool. Soc. Lond.*, 1, 1925.
- [8] *Idem.* *Geol. Mag.*, **79**, vi, 332, 1942.
- [9] BROOM, R. and ROBINSON, J. T. *Proc. zool. Soc. Lond.*, **118**, ii, 392, 1948.
- [10] CAMP, C. L. *Amer. J. Sci.*, **243**, 17, 84, 1945.
- [11] FÜRBRINGER, M. *Jena. Z. Naturw.*, **34**, 215, 1900.
- [12] KUHN[-SCHNYDER], E. *Schweiz. paläont. Abh.*, **69**, 1, 1952.
- [13] NOPCSA, F. v. *Paläont. Z.*, **5**, 161, 1923.
- [14] *Idem.* *Zbl. Miner. Geol. Paläont.*, **B**, 265, 1925.
- [15] *Idem.* *Ibid.*, 252, 1930.
- [16] OSBORN, H. F. *Mem. Amer. Mus. nat. Hist.*, **1**, viii, 449, 1903.
- [17] PARRINGTON, F. R. *Ann. Mag. Nat. Hist.*, (10), **16**, 197, 1935.
- [18] PEYER, B. *Abh. schweiz. paläont. Ges.*, **50**, 7, 1931.
- [19] *Idem.* *Ibid.*, **59**, 1, 1937.
- [20] *Idem.* *Ecl. geol. Helv.*, **32**, 203, 1939.
- [21] ROMER, A. S. *Amer. J. Sci.*, **245**, 19, 1947.
- [22] VERSLUYS, J. *Zool. Jber.*, Suppl. **15** (Festschr. J. W. Spengel, 2), 545, 1912.
- [23] WATSON, D. M. S. *Geol. Mag.*, **79**, ii, 81, 1942.
- [24] *Idem.* *Obit. Not. roy. Soc.*, **8**, 37, 1952.
- [25] WILLISTON, S. W. *J. Geol.*, **22**, 364, 1914.
- [26] *Idem.* *Ibid.*, **25**, 410, 1917.
- [27] YOUNG, C. *Amer. J. Sci.*, **246**, 711, 1948.

BIBLIOGRAPHY

- ROMER, A. S. 'Vertebrate Paleontology' (2nd ed.). 1945.
- GREGORY, W. K. 'Evolution Emerging.' 1951.

Book reviews

HONOUR TO CHARLES SINGER

Science, Medicine and History. Essays in honour of Charles Singer. *Two volumes, edited by E. Ashworth Underwood. Pp. 563 and 646. Oxford University Press, London. 1953. 11 gns. the set of two volumes.*

It is a matter for genuine satisfaction that the steadfast and richly fruitful devotion of a long career to science and scholarship should be thus recognized and honoured. It is truly a magnificent tribute to the life's work and inspiring influence of Charles Singer as investigator, teacher, and powerful advocate of the study of medical and scientific history, that Dr Ashworth Underwood has assembled, edited, and brought to publication. It presents a most impressive array of contributions of great distinction, from scientists and scholars of many countries who belong to the wide circle of Dr Singer's friends and admirers. Its organization and production must have involved a labour of affection over an extended period, for several of the eminent contributors have already been dead for some years. No fewer than ninety in all have filled these two handsome volumes with essays and articles of the most widely varied character and interest, but having the common aim of casting new light, from their different angles, on the history of medicine, and that of a much more extensive range of experimental science and philosophical speculation. Their object was to honour the man whose outstanding services to scholarship, in this wide field of their common interests, they all desire to acknowledge, and to applaud; it would be difficult, impossible indeed, to imagine a handsomer tribute to any man's life-work and achievement, or a more heart-warming expression of personal regard. It is, of course, impossible even to attempt, within any reasonable limits, a systematic review of a work so richly composite. The component articles are, naturally, of various lengths, styles, manners, and essential contents, from miniature monographs on particular documents from antiquity, on local schools, systems, or societies, or on periods of special scientific or medical developments, to revised interpretations of well known philosophical systems, and even to direct recollections of eminent teachers and investigators of recent times. It may be permissible, perhaps, to say a word of special welcome to

this latter recognition of the potential value, to the future historians of medicine and science, of such intimate reminiscences of the men who, in the contemporary judgments of their pupils and admirers, seem likely to retain such important stature in the longer perspective of future appraisal.

The book opens with an admirable sketch of Charles Singer's life by the editor. It will be of great interest to many to learn that Singer began his scientific career as a practical research worker in pathology, both in England and, later, after his marriage, for a period in Germany; and that, in his researches on cancer, he appears to have been only just anticipated, by another investigator, in a discovery which earned the award of a Nobel Prize. It is of interest also to recognize the determinant effects, on his eventual embarkation on a career which this book has been produced to celebrate, of his marriage to Dorothea Waley Cohen and of the recognition of the natural line of his genius by Sir William Osler.

As for the rest of the book's rich variety of learned and attractive contents, there are many articles presenting the results of historical and scholarly researches of great intrinsic importance, such as that by Leake, Larkey, and Lutz on 'The management of fractures according to the Hearst Papyrus'; by Wickersheimer (in French) on the medical texts of Chartres of the 9th, 10th, and 11th centuries; by Rabin on an Arabic text dealing with the skeleton by Ibn Jami', the Jewish physician to Saladin, Sultan of Egypt in the 12th century; and a great range of others of comparable interest and importance. It is, of course, impossible to mention all, or to pretend even to make a representative selection, where each is of such separate and individual interest, and all are of so high a standard. It must be sufficient, however invidious, just to name one which happens to have struck the reviewer's wayward fancy, from each of the other 'books,' representing successive periods, into which the editor has divided the whole work. Thus, from Book III (The Renaissance), we select Cole's 'History of Albrecht Dürer's Rhinoceros,' profusely and admirably illustrated; from Book IV (The New Philosophy), A. W. Mayer's 'The Elusive Human Allantois in Older Literature'; from Book V (The Insurgent Century), Le Fand's 'Jean Martet,

a French Follower of William Harvey'; from Book VI, Underwood's 'Von Berger and his Text-Book of Human Physiology'; from Book VII (The 19th Century and After), Cave's 'Richard Owen and the Discovery of the Parathyroid Glands'; and from Book VIII (*Conspectus Generales*), Darlington's racily critical 'Purpose and Particles in the Study of Heredity.' These are just random samplings indicative of the richness offered in these splendid volumes.

The editor and the Oxford University Press have done their parts admirably to ensure a really worthy presentation of this collection of testimonial offerings. A detailed textual criticism of such a work would demand months, or years, of study. Just because it catches the eye, a small error in the legend to Professor Franklin's sketch-portrait of the late Ernest H. Starling may be mentioned. His friends would have wished Starling to be knighted; but he never was. There is a full bibliography of Charles Singer's writings (over 410 items), and a very complete index. Altogether a noble tribute to a life of great scholarly achievement and inspiring leadership.

H. H. DALE

LOUIS PASTEUR

Un Maître de l'Enquête Scientifique, Louis Pasteur, by J. Nicolle. Pp. 222. *Editions du Vieux Colombier, Paris. 1953. Fcs 610 net.*

The author of this book set out—and succeeded perfectly in his aim—to reveal the mental processes which guided that incomparable 'magician' Pasteur in the great researches which occupied his life. Such an exposition of his reasoning makes apparent both its rigour and its admirable simplicity. Further, it reveals a unity in Pasteur's publications despite the diversity of their topics, which range from crystallography through fermentation processes to contagious diseases. Many readers will share the experience of the writer of the preface, P. Lépine: they too will find a lively pleasure in following the 'why and how' of Pasteur's reasoning, and reading this book should prove an excellent prelude to the vocation of research.

There are separate accounts of ten different inquiries—tartaric acid; fermentations; so-called spontaneous generation; vinegar; wine; silk; beer; carbon; chicken-cholera; and rabies.

R. DELABY

ORGANIC CHEMICAL DICTIONARY
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*Editors-in-chief: Sir Ian Heilbron and
H. M. Bunbury. Editors: A. H. Cook and
E. R. H. Jones. New edition in four
volumes. Pp. 654, 845, 838, and 694
respectively. Eyre and Spottiswoode Limited,
London. 1953. £28 net.*

This completely new and considerably augmented edition of Heilbron's 'Dictionary' will be welcomed by all organic and biological chemists. Those who have not ready access to Beilstein's *Handbuch* will find this work extremely useful for very many purposes, though obviously not completely exhaustive in its scope. Even chemists who have access to all the members of the rapidly increasing Beilstein family will—when pressed for time or in moments of physical or mental exhaustion—turn to this dictionary in the hope of finding quickly some leading reference, some physical constant or structural formula. Human nature being what it is, these occasions will be frequent, and the seeker will very often be rewarded by finding exactly what he wants.

Having regard to the limits which the compilers have set themselves it is impossible to speak too highly of the results of their labours. The arrangement is alphabetical, and where this simple system might be expected to become complicated the difficulties are smoothed away by the enunciation of a few guiding principles, illustrated by formulae showing straight and branched chains and ring systems with numbered carbon atoms. The introduction contains a list of the names and formulae of the principal substituents, and the titles (full and abbreviated) of the 145 journals to which references are made.

The information that is usually given for each substance cited includes the full structural formula (where known), melting-point, boiling-point, appearance, solubility, natural occurrence, and from two to six (and sometimes more) references. Over 2500 new compounds have been added since the last edition, and the literature has been surveyed up to the end of 1950. Many references from the years 1951–3 are, however, included, those of biochemical significance having received special attention.

Chemists who are working in the field of natural products will particularly welcome the success with which the alphabetical system enables details of the most varied substances, often having most unusual and attractive

structures, to be found with the greatest ease. The information provided in this field is most comprehensive and stimulating, and will be found invaluable. Thus, by chance, the reviewer came across a reference to thevetose, an example of the natural partially methylated sugars, very few of which have come to his notice.

On the other hand, there seems to be no mention of any of those carboxylic derivatives of alkyl or alkylarylsulphonium salts which, under the historic name of thetins, have recently attracted attention in America, where the group name is becoming widely used. Several of the tropolones are cited, however, and also the remarkable heterocyclic sulphur compound thia-adamantane, recently isolated from petroleum by Birch and his colleagues. The no less interesting parent compound adamantane, another petroleum product, also finds a place along with the hormones A.C.T.H., corticosterone, and cortisone; streptomycin, actinomycin, and atebrian (better known as mepacrine, the antimalarial drug) are also cited. The penicillins and their degradation products occupy seven pages.

Research workers in synthetic organic chemistry, and those concerned with the intermediate products of the dye-stuff industry, will find that their needs have been carefully considered. The book is useful and labour-saving, but is also a valuable contribution to chemical literature and a source of intellectual stimulus and satisfaction to those who can 'turn but a stone and start a wing.'

FREDERICK CHALLENGER

THE CRYSTALLINE STATE

The Determination of Crystal Structures, by H. Lipson and W. Cochran. Pp. ix + 345. G. Bell and Sons Limited, London. 1953. 50s. net.

This book is the third and final volume of the important series on 'The Crystalline State,' edited by Sir Lawrence Bragg. It takes up the problem of structure determination from the point at which the experimental work has been completed, and since it contains a discussion of the reliability of final results in terms of the accuracy of the experimental measurements, it will not become outdated by improvements in experimental technique.

The authors have themselves made, and are still making, outstanding contributions to the subject in both theory and practice, and the inclusion in a book published in 1953 of references to

papers published in the same year is a striking indication of the fact that even the specialist could gain little more by consulting newly published papers. Indeed, the mathematical nature of much modern theory concerning the solution of the phase problem in crystal structure analysis has meant that individual contributions, written with varying degrees of clarity and differing nomenclatures, have often appeared more formidable than the admirably unified presentation in this book shows them to be.

We cannot be too grateful to the authors for rendering such a signal service to all those interested in structural crystallography. While they rightly remind us that there is no substitute for experience in successful structure determination, this book is the nearest thing to a substitute that we are likely to find.

KATHLEEN LONSDALE

FLAMES

Flames. Their Structure, Radiation and Temperature, by A. G. Gaydon and H. G. Wolfhard. Pp. 340, with half-tone and line illustrations. Chapman and Hall Limited, London. 1953. 55s. net.

Combustion reactions have been studied so extensively by chemists and physicists, and their technical importance is so great, that today they can hardly be presented within a single treatise. In this book, of moderate size, the authors have restricted the scope to 'stationary flames, with the emphasis on the physical rather than the chemical viewpoint.' Further, they have especially concentrated on 'the measurement of flame velocity, the theories of flame propagation, the method of carbon formation in flames, flame radiation, the measurement of high flame temperatures and ionization in flames.'

It is obvious from this survey that the field covered is still very wide, and the guidance of the two authors, who have a great number of original contributions to their credit, will be very welcome to many. The book is richly illustrated with figures, diagrams, photographs of spectra, and a few coloured pictures of flames.

To avoid the impression that the book is confined to the subjects singled out by the authors in their preface, it should be mentioned that a few short, but highly instructive, paragraphs are also devoted to isolated subjects like sensitive flames; flames containing nitrogen oxides, diborane, or fluorine; atomic flames; and the combustion of

solid particles. These few hints must suffice to indicate the wealth of material the book offers.

F. A. PANETH

NUCLEAR PHYSICS

Experimental Nuclear Physics, edited by E. Segrè. Volumes I and II. Pp. 789 and 600 respectively. John Wiley and Sons Inc., New York; Chapman and Hall Limited, London. 1953. 120s. and 96s. net.

'A cooperative effort like the Geiger-Scheel *Handbuch der Physik* seemed the only solution,' comments the editor of this three-volume work on nuclear physics (the third volume is still to be published). The high standard implied by this comparison is brilliantly maintained throughout a series of contributions, each written by an authority. Topics covered are detection methods; passage of radiation through matter; nuclear moments and statistics; nuclear two-body problems and elements of nuclear structure; charged particle dynamics and optics; relative isotopic abundances of elements; atomic masses; nuclear reactions; the neutron. From a work of such encyclopaedic character it would be invidious to single out individual contributions and impossible to do equal justice to all. Suffice it to say that the present reviewer studied those parts in which he feels himself competent to look for mistakes, and found very few—and those trivial ones.

Although the title of this work contains the word 'experimental', it would be wrong to assume that this is a mere catalogue of experiments. Each account is set firmly against its background of theory, and the work as a whole contains more theory than any book on theoretical nuclear physics except that by Blatt and Weisskopf, to which it would appear to be a companion. The experiments are clearly written and excellently illustrated with diagrams, graphs, and tables, and the whole is so beautifully produced that it is difficult to cavil at its price.

L. R. B. ELTON

SYMBIOSIS

Endosymbiose der Tiere mit Pflanzlichen Mikro-organismen, by Paul Buchner. Pp. 772. Verlag Birkhäuser, Basle. 1953. Paper covers, Sw. fcs 62.40; bound, Sw. fcs 66.50 net.

In this excellent book Dr Buchner correlates much general knowledge with the results of his own 40 years' study of symbiosis. The work is divided into three main parts. The first deals with the discovery and extent of endosymbiosis. The second, special, part des-

cribes the various symbiotes, their form, biology, and host relationships, etc. Here the grouping is based neither on the systematics of the hosts, nor on that of the symbiotes themselves, but on the food or physiology of the hosts. Seven main groups are recognized: symbiotes in animals feeding respectively on materials rich in cellulose, on tree fluxes, on plant sap, on keratin, and on mixed foods; those in animals capable of producing light; and those which are restricted to the excretory organs.

The third, general, part discusses the location of symbiotes, the means by which they are transferred to the next generation, their development during the embryonic and post-embryonic periods of the host, and the economics of their association. Here also is discussed the part symbiotes can play in elucidating the evolutionary history of the hosts. The work is very clearly written and copiously illustrated.

F. BARANYOVITS

ORGANIC ANALYSIS

Estimation of Organic Compounds, by F. Wild. Pp. 239. Cambridge University Press, London. 1953. 25s. net.

No book on quantitative organic analysis has been published in Britain since Thorpe and Whiteley's 'Organic Chemical Analysis' in 1925: this is now out of date and has long been out of print. The publication of Dr Wild's book is therefore timely.

The volume is divided into seven chapters: olefines—solid, liquid and gaseous; alcohols, enols, and phenols; mercaptans; aldehydes and ketones; amines and amino compounds; nitro, nitroso, and cyano compounds, isocyanates and isothiocyanates; other groups including acetyl, benzoyl, methoxyl, ethoxyl, propoxyl, butoxyl, methylimino, ethylimino, methyl and ethyl groups attached to sulphur, and methyl groups attached to carbon. The ultimate analysis of organic compounds is not discussed. The various methods for determining the different groups are described in varying detail, the sources of error are mentioned as well as means for eliminating them or reducing them to a minimum; the percentage accuracy is given for those procedures which are described in full. The author has not hesitated to make use of physical methods where applicable. Literature references are given throughout.

As Dr Wild points out in his preface, quantitative organic analysis is rarely dealt with adequately in the teaching

of chemistry, and there can be little doubt that his book will help to stimulate interest in this subject. The book should prove of great value to students in the final years of the honours degree course and to research workers in organic chemistry.

A. I. VOGEL

METEOROLOGY IN HOLLAND

Koninklijk Nederlands Meteorologisch Instituut 1854–1954. *Centenary Celebration Volume published by the Royal Netherlands Meteorologica Institute*. Pp. 469, with colour, half-tone, and line illustrations. Staatsdrukkerij-en Uitgeverijbedrijf, 's-Gravenhage. 1954. N.p.

For two quite practical reasons, there was a great upsurge of interest in meteorology in the middle of the nineteenth century. The first reason was the realization that application of contemporary knowledge about ocean winds could materially reduce the times of passage of the great clipper sailing-ships. The second was a determination to try to warn shipping of the existence of tempestuous winds. So it was that most of the maritime nations of the world founded their state meteorological services in the 1850's. The Dutch were among the first to do so, and the service then founded has today had the happy thought of celebrating its centenary by producing a magnificent volume telling the history of the service. It is a distinguished history, with a distinguished line of directors from Professor Buys Ballot, the founder, to Professor Vening Meinesz, the last to have completed his term of office.

The book is in three parts. The first is largely historical, with notable sections on the work undertaken in international meteorology, including the international polar years 1882–3 and 1932–3. The second is on the present structure and activities of the service, the activities including not only meteorology but physical oceanography and most other parts of geophysics. Finally, there are ten original papers on fields of geophysical research in which present members of the service are particularly active. One of these papers, appropriately enough, surveys the evidence on climatic change from the instrumental records at De Bilt over the last 200 years. The book is beautifully illustrated, partly with coloured plates showing various states of the sky, and is a service to science as well as a homage by the present Dutch service to its forebears.

P. A. SHEPPARD

Some books received

(Note. Mention of a book on this page does not preclude subsequent review.)

BIOLOGY

Animal Biochromes and Structural Colours, by Denis L. Fox. Pp. 379. Cambridge University Press, London. 1954. 60s. net.

Freshwater Microscopy, by W. J. Garnett. Pp. 300. Constable and Company Limited, London. 1954. 30s. net.

An Introduction to Bacterial Physiology, by Evelyn L. Oginsky and Wayne W. Umbreit. Pp. 416. W. H. Freeman and Company, San Francisco; Bailey Brothers and Swinfen Limited, London. 1954. 51s. net.

Microbiology, An Introduction, by Ernest A. Gray. Pp. 175. Crosby Lockwood and Son Limited, London. 1954. 10s. 6d. net.

Résistance et Soumission en Physiologie, by H. Laborit. Pp. 120. Masson et Cie., Paris. 1954. Fcs 650 net.

CHEMISTRY

L'Analyse Spectrale Quantitative par la Flamme, by R. Mauvrodineanu and H. Boiteux. Pp. 247. Masson et Cie., Paris. 1954. Paper covers, fcs 3800; bound, fcs 4300.

Catalysis, Volume I, edited by Paul H. Emmett. Pp. 394. Reinhold Publishing Corporation, New York; Chapman and Hall Limited, London. 1954. 80s. net.

Chimiosynthèse et Photosynthèse, by Roger Bwat. Pp. 208. Presses Universitaires de France, Paris. 1954. Fcs 720 net.

Les Constantes Physiques de Composés Organiques Cristallisés, by J. Timmermans. Pp. 558. Masson et Cie., Paris. 1954. Fcs 5200 net.

French-English Dictionary for Chemists (2nd edition), by Austin M. Patterson. Pp. 476. John Wiley and Sons Inc., New York; Chapman and Hall Limited, London. 1954. 52s. net.

The Infra-red Spectra of Complex Molecules, by L. J. Bellamy. Pp. 323. Methuen and Company Limited, London. 1954. 35s. net.

Isotopic Tracers, by G. E. Francis, W. Mulligan, and A. Wormall. Pp. 306. The Athlone Press, London. 1954. 37s. 6d. net.

Lehrbuch der Organischen Chemie (12th edition, revised), by Paul Karrer. Pp. xx + 949. Georg Thieme Verlag, Stuttgart. 1954. DM 59.70 net.

Methoden der Organischen Chemie (Houben-Weyl) 4th revised edition, edited by Eugen Müller. Georg Thieme Verlag,

Stuttgart. Vol. II: Analytische Methoden. Pp. xxii + 1070. 1953. DM 139 net. Vol. VII, Part 1: Sauerstoffverbindungen II, Aldehyde. Pp. xxiii + 596. 1954. DM 82 net. Vol. VIII: Sauerstoffverbindungen III. Pp. xviii + 776. 1952. DM 98 net.

Qualitative Inorganic Analysis, by G. Charlot. Pp. 354. Methuen and Company Limited, London. 1954. 42s. net.

Quantitative Organic Analysis via Functional Groups (2nd edition), by Sidney Siggia. Pp. 227. John Wiley and Sons Inc., New York; Chapman and Hall Limited, London. 1954. 40s. net.

Semi-Micro Organic Preparations, by J. H. Wilkinson. Pp. 94. Oliver and Boyd, Edinburgh. 1954. 8s. 6d. net.

The Structures and Reactions of the Aromatic Compounds, by G. M. Badger. Pp. 456. Cambridge University Press, London. 1954. 63s. net.

Vegetable Fats and Oils, by E. W. Eckey. Pp. 836. Reinhold Publishing Corporation, New York; Chapman and Hall Limited, London. 1954. 132s. net.

GENERAL

Discovery Reports, Vol. XXVI; Open Boat Whaling in the Azores, by Robert Clark. Pp. 281-324. Cambridge University Press, London. 1954. 21s. net.

A Discussion on the Maintenance of Cultures by Freeze Drying. British Commonwealth of Nations Scientific Liaison Offices. Pp. 48. Her Majesty's Stationery Office, London. 1954. 5s. net.

Instrumental Analysis, by John H. Harley and Stephen E. Wiberley. Pp. 440. John Wiley and Sons Inc., New York; Chapman and Hall Limited, London. 1954. 52s. net.

The Steel Skeleton, Volume I: Elastic Behaviour and Design, by J. F. Baker. Pp. 206. Cambridge University Press, London. 1954. 42s. net.

HISTORY OF SCIENCE

Astrology and Alchemy, by Mark Graubard. Pp. 382. Philosophical Library, New York. 1953. \$5 net.

Im Banne der Chemie; Carl Bosch, Leben und Werk, by Karl Holdermann. Pp. 336. Econ-Verlag, Düsseldorf. 1954. DM 14.80 net.

MEDICAL

Deutsch-Englisches, Englisch-Deutsches Wörterbuch für Ärzte (in two volumes),

Volume I, by F. Lejeune; Volume II, by F. Lejeune and W. E. Bunjes. Pp. xx + 1352 and xl + 1737 respectively. Georg Thieme Verlag, Stuttgart. 1951 and 1953. DM 24 and 58.50 respectively.

Physiological Acoustics, by Ernest Glen Wever and Merle Lawrence. Pp. 454. Princeton University Press, Princeton; Geoffrey Cumberlege, London. 1954. 80s. net.

Praktische Arbeitsphysiologie, by Gunther Lehmann. Pp. 355. Georg Thieme Verlag, Stuttgart. 1953. DM 33 net.

METALLURGY

Engineering Steels, by Leslie Aitchison and William I. Pumphrey. Pp. 923. Macdonald and Evans Limited, London. 1953. £5 5s. net.

The Structure of Metals and Alloys, by William Hume-Rothery and G. V. Raynor. Pp. 363. The Institute of Metals, London. 1954. 35s. net.

Text-book of Metallurgy, by A. R. Bailey. Pp. 560. Macmillan and Company Limited, London. 1954. 30s. net.

PHYSICS

L'Instabilité en Mécanique, by Y. Rocard. Pp. 240. Masson et Cie., Paris. 1954. Fcs 1200 net.

Le Microscope à Contraste de Phase et le Microscope Interférentiel, by Maurice Françon. Pp. 149. Editions du Centre National de la Recherche Scientifique, Paris. 1954. Fcs 1000 net.

Numerical Tables of Nuclear Physics, by Charles Noël Martin (French and English texts). Pp. 258. Gauthier-Villars, Paris. 1954. Bound, 44s. 11d.; unbound, 36s. 9d. net.

The Quantum Theory of Radiation (3rd edition), by W. Heitler. Pp. 430. Oxford University Press, London. 1954. 45s. net.

Théorie Générale des Particules à Spin (Méthode de Fusion), by Louis de Broglie. Pp. 209. Gauthier-Villars, Paris. 1954. Fcs 2500 net.

TECHNOLOGY

Minerals for the Chemical and Allied Industries, by Sydney J. Johnstone. Pp. 692. Chapman and Hall Limited, London. 1954. 75s. net.

The Post-War Expansion of the U.K. Petroleum Industry, edited by George Sell. Pp. 220. The Institute of Petroleum, London. 1954. 25s. net.

Notes on contributors

SIR ROBERT ROBINSON,
O.M., M.A., D.Sc., LL.D., F.R.S.,

Was born in 1886 and was educated at Fulneck School, near Leeds, and the University of Manchester. Appointed professor of organic chemistry in the University of Sydney in 1912, he has since held several professorial chairs, and since 1930 has been Waynflete Professor of Chemistry in the University of Oxford. His scientific work has been concerned with the structure and synthesis of such natural products as alkaloids and anthocyanins, and with the application of electronic theories to the mechanism of reaction. He has been President of The Royal Society and of The Chemical Society, and is a medallist of these and many other learned bodies. He is President-elect of the British Association for the Advancement of Science.

A. URBAIN,
Docteur-ès-Sciences,

Was born at Le Havre in 1884, and became a veterinary surgeon in the army in 1906. Continuing his studies of natural science, he obtained his doctorate in 1920. He joined the *Muséum National d'Histoire Naturelle* in 1931, and two years later was appointed director of the collections of living animals. In 1942 he was elected Director, and is now Honorary Director. The flourishing state of the zoological gardens in the *Parc Zoologique du Bois de Vincennes* is largely due to his personal efforts.

J. C. G. NOUVEL,
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Was born at Nantes in 1909, and obtained the diploma of doctor of veterinary science in 1931; he then continued his studies at the Faculty of Sciences and became *Licencié-ès-Sciences* in 1937. He joined the *Muséum National d'Histoire Naturelle* in Paris in 1935 as assistant to the professor of ethology of wild animals, and has collaborated since that date with Professor Urbain. He was appointed *Sous-directeur* of the laboratory of the *Muséum* in 1947.

H. GREINACHER,
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Was born in Switzerland in 1880 and was educated at the University of Berlin, graduating in 1904. Subsequently he was assistant in the universities of Berlin, Heidelberg, Geneva, and Zürich. At the latter he was appointed lecturer in 1907 and professor of radiology in 1916. In 1924 he was appointed Professor of Physics and Director of the Physics Institute and Meteorological Observatory, University of Bern, appointments which he held until his retirement in 1952. Has carried out much work, chiefly experimental, in various fields of physics, particularly in those relating to high-tension and measuring technique.

E. GÄUMANN,
Ph.D.,

Was born at Lyss, Switzerland, in 1893, and graduated from the University of Bern in 1917; he afterwards studied for a year at the University of Uppsala. From 1919 to 1922 was plant pathologist in the agricultural department, Dutch East Indies; 1922-5, botanist at the Swiss Agricultural Experimental Station at Zürich-Oerlikon. In 1925 he was appointed Lecturer in the Institute for Special Botany of the Swiss Federal Institute of Technology at Zürich; two years later he was appointed Professor and Director. He has an international reputation as a plant pathologist.

W. H. MILLS,
M.A., Sc.D., F.R.S.,

Was born in 1873 and was educated at Uppingham School and the Universities of Cambridge and Tübingen. Is Emeritus Reader in Stereochemistry at Cambridge, where he is a Fellow, and during the years 1940-8 was President, of Jesus College. Is a Davy Medallist of The Royal Society, and a Longstaff Medallist of The Chemical Society, of which he was President 1941-4.

E. S. HORNING,
M.A., D.Sc.,

Was born at Sydney, Australia, in 1900, and is a graduate of the universities of Oxford and Melbourne. In the war of 1914-18 he served with the Australian Imperial Forces. During the tenure of a Rockefeller Medical Research Fellowship he worked at the *Kaiser Wilhelm Gesellschaft* in Berlin-Dahlem, at other research centres in Europe, and later at the Washington University Medical School, St Louis. In 1933 he was awarded a Beit Medical Research Fellowship and returned to London to work at the Imperial Cancer Research Fund Laboratories, where he later became a member of the scientific staff. During the last war he served with the Royal Naval Volunteer Reserve. At the conclusion of the war he was appointed to the Readership in Experimental Pathology, tenable at the Royal Cancer Hospital. His numerous publications have been mainly in the sphere of experimental pathology.

E. KUHN-SCHNYDER,
D.Sc.,

Was born at Zürich in 1905, and studied natural science at the Federal Technical High School there, graduating in zoology in 1932. From 1931 to 1940 he was chief teacher of mathematics and natural sciences, and later principal, in the Regional School at Bremgarten. In 1940 he became senior assistant at the Zoological Museum, and in 1947 lecturer in comparative anatomy and palaeontology at the University of Zürich. Since 1950 he has been directing an extensive new excavation on Monte San Giorgio. He is author of *Die Tierwelt der prähistorischen Siedlungen der Schweiz* (with the late K. Hescheler, 1949), *Die Geschichte der Wirbeltiere* (1953), as well as of many articles on palaeontological research.

*Made and printed in Great Britain at THE KYNOCH PRESS, Wotton, Birmingham, 6, for the publishers,
IMPERIAL CHEMICAL INDUSTRIES LIMITED, London, S.W.1*

